MODERN PRACTICAL BUILDING

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PREFACE TO THE REVISED EDITION

This work is intended to give a practical and adequately illustrated description of modern building materials and methods.

The crafts and trades of building construction are now numerous and complex. Until recent years the craftsman needed only a good grasp of the elementary principles of his craft (brickwork, carpentry, masonry and so on) and sound practical experience. If ambitious, he could take on a foreman's or clerk of works' job when opportunity offered. The builder needed no more than a working knowledge of two or three staple trades. Materials and craftsmanship were traditional.

Modern scientific research, invention and manufacturing processes have completely altered the picture. We have new materials with many ingenious methods of application. The older materials have been improved and new applications devised. We have an imposing mass of scientific information on general building problems, and we have the entirely new field of mechanisation, prefabrication and shop assembly designed for high-speed erection with reduction of site labour.

Since the first edition of this work was published, training and apprenticeship for the building industry have been drastically reorganised and working conditions greatly improved, by the co-operation of the Government with representative bodies of all branches of the industry. These new schemes make the industry as attractive to youth as any other, and ensure that talent will be given every opportunity and encouragement.

In revising this work, every effort has been made to give the practical man up-to-date information in language not too technical or specialised. In this I have had the kind assistance of many firms, societies and individuals, most of whom are mentioned in the text.

Edgar Lucas.

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MODERN PRACTICAL BUILDING

VOL. I

CHAPTER 1

PLANNING AND DESIGN

In the design of modern buildings planning for practical convenience and amenity is the dominant factor. The elevations arise from the plan. Architectural effect should be considered when planning the layout of rooms, windows, doors, etc., but no serious sacrifice of the practical amenities of the plan should be made. Modern architecture is functional and pleases most when it aptly expresses the purpose and structure of the building. In this it is not revolutionary. The buildings of the great traditional periods of architecture do the same according to the purposes, materials and structural systems of their time.

We have a different and wider range of purposes, materials and systems. This is an age of machine production—not hand production—and it is natural that we should build according to the requirements and opportunities of our time.

Modern building is complex because our requirements and opportunities are complex. Careful study of planning requirements and structural systems is necessary before we can design satisfactory buildings. Even then a fine sense of proportion, form, detail and colour is necessary to enable the architect to create a beautiful building.

Site.—The site should give a reasonable opportunity to solve the planning and structural problems. Unfortunately many sites are bought before an architect is consulted, and in some cases great difficulties are experienced because the site is not suitable.

The following are the chief factors which should be considered in selecting the site :

(1) Town-planning requirements. Under a town-planning scheme certain areas may be reserved for houses, others for shops, and others for commercial or industrial buildings. Existing roads may be widened.

(2) Building by-laws and regulations. Regulations for special buildings such as factories or cinemas.

(3) Restrictions by the vendor or lessor of the land.

(4) Services: water, sewer, electricity, gas.

(5) Transport: road, rail, canal, air. For industrial and commercial buildings road transport is now more important than rail or canal transport.

(6) Local amenities. For example, a housing scheme requires easy access to shops, schools and bus stops.

(7) Subsoil. This affects the cost of the buildings, especially if heavy loads are involved.

(8) Levels of the land. This also affects the cost of the building, especially one covering an extensive ground area.

(9) Aspect in relation to daylight and view.

(10) Adjoining buildings.

(11) Purpose of the new building.

(12) Floor area of the new building, and whether ground floor only or number of storeys.

When inspecting a site look for snags. The subsoil is of great importance, as it must bear the building loads (see Chapter 2). Ground near streams and rivers may be subject to flooding. The existing sewers may not be deep enough to allow drains being laid and connected from the existing site levels.

The general environment and adjoining property should be inspected. Building against adjoining buildings presents special problems. The purpose for which the new buildings are required may possibly give reasonable cause of complaint by neighbouring owners. They will naturally resent noise, vibration, noxious fumes or smells. They may have rights of light which must be respected. It saves much time and trouble to tackle these problems at the outset.

The site is considered in greater detail in Chapter 2.

PLANNING

Before the site is purchased the local authorities should be consulted regarding position and depths of sewers, water, gas and electric services. The effect of any town-planning scheme should also be enquired into. It is unlikely that permission will be given to erect a factory in an area scheduled for dwellings, though it is possible that shops may be permitted in an area scheduled for other types of buildings, even though the scheme includes sites reserved for shops. Reasonable elasticity is desirable, but the local authority will want to be satisfied that a proposed variation of the scheme is in the public interest before approving it.

The main object of a town-planning scheme is to utilise land to the best advantage of the community. This involves some sacrifice of private enterprise and aggrandisement, but in the long run the individual benefits, as the area is not only a pleasant place to live and work in, but maintains its amenities and the value of its sites and buildings.

Fig. 1 illustrates a small scale example of town planning. It will be seen that the area has various zones reserved for specific kinds of build-

Fig. 1.—Welwyn Garden City. Plan showing residential, shopping and industrial zones.

ings: dwellings, shop and business premises, and factories. And an examination of the plan will show that the best amenities have been provided for each kind of building. The houses are not too close to the main-line railway but within easy reach of the station. The factories have connections with the railway and direct access to main roads. The shopping centre and public buildings are centrally situated. There are open spaces planted with trees, and playing fields.

There is, of course, much more in town planning than this simple outline suggests, but we are concerned here merely with pointing out how it affects the selection of a site and the general amenities and environment.

ASPECT

Three factors affect the aspect of a building or individual room:

(1) Sunlight.

(2) Prevailing winds and relative exposure.

(3) Environment and views from windows.

Aspect is usually taken to mean the first of these factors, but it is better to consider all three at once.

Fig. 2 is a diagram giving the points of the compass. The second circle is divided into the twenty-four hours of day and night, and the lengths of the longest, medium and shortest days of the year are given (average for Great Britain). The directions *from* which blow most of the rain-bearing gales, cold winds and mild winds are also shown.

(1) ***Sunlight.***—The apparent motion of the sun is from east in the morning through south to west in the evening (as seen in Great Britain). The sun attains its maximum altitude at midday, at which time it is due south. The altitude is much greater in mid-summer than in mid-winter and, of course, the hours of sunlight are much longer in mid-summer.

It follows that if maximum sunlight is desired throughout the day the windows should face south. If no sunlight is desired they should face north. If sunlight is preferred in the morning they should face east, and if preferred in the afternoon they should face west.

The following are the aspects usually preferred for:

Houses, Bungalows and Flats

S. to S.W.—Living room, drawing room, lounge, sun lounge, loggia, terrace, playroom, dining room.

E. to S.E.—Dining room, kitchen, night nursery, breakfast room, bathroom, bedrooms.

N. to N.E.—Larder, dairy, studio.

Individual preference and the general environment may modify these aspects. The practical difficulties of planning may prevent all rooms having the aspect desired.

The tendency in the modern house is to have as much sunlight as possible. Exterior blinds can be fitted to give shade in very hot weather. In some cases it is worth while glazing with heat-absorbing glass.

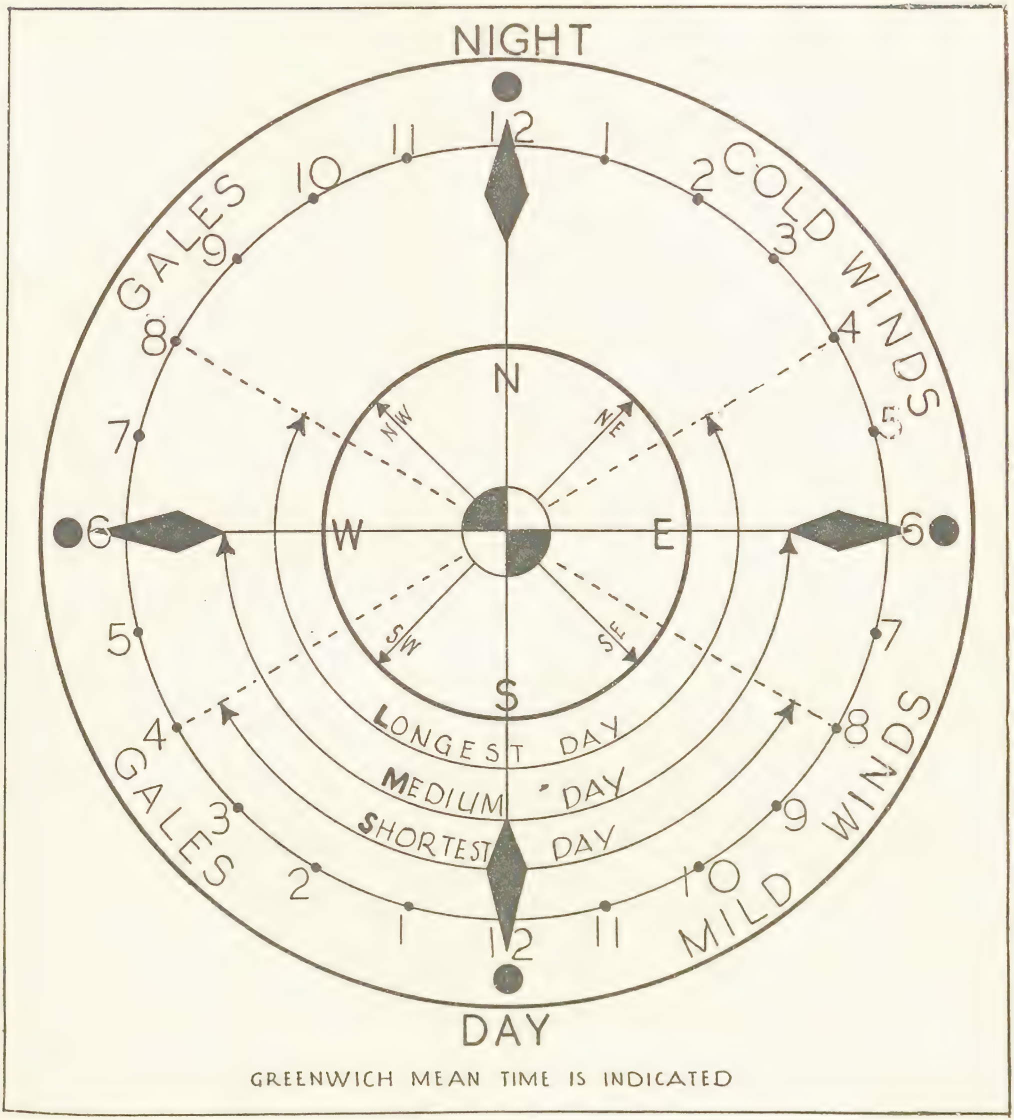


Fig. 2.—Aspect diagram.

Schools

S.E.—Classrooms.
N.W. to N.E.—Handicraft rooms and workshops, library.
N.—Studios, drawing rooms, laboratories.
S.E. to S.W.—Masters' rooms, office.

Factories

N. to N.E.—Workshops, machine shops, foundries, warehouses, drawing office, stores.
S.E. to S.W.—Offices.

Hospitals

E. or W.—Wards (wards with windows on E. and W. side walls).

S.—Solariums and sun balconies.

N.—Operating theatres.

Shops

N.E. to N.W.—Shop fronts.

Gardens and Grounds

A southerly aspect preferable. Buildings should not shade the flower beds and borders from the south. Ground sloping southwards is an advantage for flowers.

(2) ***Prevailing Winds and Relative Exposure.***—The prevailing rain-bearing winds are westerly. The western side of Britain has a much higher rainfall than the eastern, as the moisture-laden atmosphere coming in from the Atlantic is precipitated on the hilly western seaboard. This causes the atmosphere on the flat eastern side to be comparatively dry.

Walls exposed to westerly winds may admit damp unless special precautions are taken. Cavity walls and deep eaves projection are advisable. Doors should have porches or canopies.

If the building is exposed to north-easterly winds, it is inadvisable to have many doors and windows on this side. They tend to admit draught and cold.

The shelter of trees and other buildings to the north, west and east is desirable. As mild winds come from the south and south-east (and also most of the sunlight) these aspects should be open, and are also suitable for large window areas.

(3) ***Environment and Views.***—With some buildings this is of great importance. The principal living rooms and bedrooms of a house should face any pleasant view, even if aspect factors (1) and (2) have to be sacrificed to some extent.

A building can sometimes be so placed on the site, and the levels of floors so arranged, that the best advantage can be taken of limited views.

Aspect generally should be a reasonable compromise between factors (1), (2) and (3). Which is the most important depends on local conditions and the purpose of the building.

HOUSES

In the modern house convenience and labour saving in working are essential because most houses have to be run with little or no paid assistance. The plan of a small house must be compact and the rooms arranged so that the housewife has to take the minimum number of steps in order to prepare meals, wash clothes, wash-up and clean the rooms.

The reduction of such labours to a minimum depends, however, on equipment as well as layout. This is often overlooked, and unfortunately labour-saving equipment is still rather costly, though as the demand for it increase prices tend to drop.

The Labour-saving House.—We can summarise the above requirements as follows:

Planning

Ease of access. In the kitchen everything should be within easy reach. There should be easy access from kitchen to dining room, and a serving hatch should connect the two rooms.

Compact planning to reduce walking when working.

Plenty of daylight in all rooms. This greatly facilitates working and reduces strain.

Equipment

The proportion of cost reserved for equipment should be higher than is usual. The following might be considered extravagant in a small house, but such equipment will greatly reduce labour and strain in working:

Stainless-steel sink and drainer.

Special kitchen cupboards and fittings, planned by the architect to occupy convenient positions.

Refrigerator, electric or gas operated.

Domestic electric machines for washing, mincing, ironing, etc.

Gas or electric cooking stove with thermostatic control.

Hood over cooking stove to take away fumes and steam.

Serving hatch between kitchen and dining room. This should have double doors and ledge of impervious material. It should be near sink draining board so that the tray does not have to be carried across the kitchen.

Impervious covering to walls, such as glazed tiles or coloured glass. Flooring of tiles, rubber or cemented linoleum, with coved skirting.

Exhaust fan for use in hot weather.

At least two kitchen lighting points. One over working table.

Central heating with auxiliary electric or gas fires.

Electric plugs in each room and in hall and landing for connecting portable apparatus.

Electric vacuum cleaner.

Planning the House.—The ideal plan cannot be devised since personal preferences and practical restrictions (especially in the case of a small house) operate against any theoretical ideal. If a reasonable compromise is achieved without any very bad planning points resulting, this is satisfactory.

The plans of small semi-detached houses tend to become standardised. The most common type is that illustrated in Fig. 3. It is compact and economical, can be built on a narrow site, has no projections at back or front to restrict light or view, and on a site of about 30 feet width there is space at the side for a garage.

Its main fault is that the rooms are too small for a family of only three or four, let alone for a large family. In particular it lacks a living room

of reasonable size. By having one large living room, instead of a dining room and lounge or parlour, the family have room to sit and move in comfort, though this operates against privacy, since there is no second room for study or retirement unless a bedroom is used.

Clearly the average small house needs to be increased in size to enable a living room at least 16 × 12 feet to be planned, in addition to a smaller room on the ground floor.

Another solution is to make the kitchen large enough to use for meals and to have a separate scullery for washing, ironing and odd jobs.

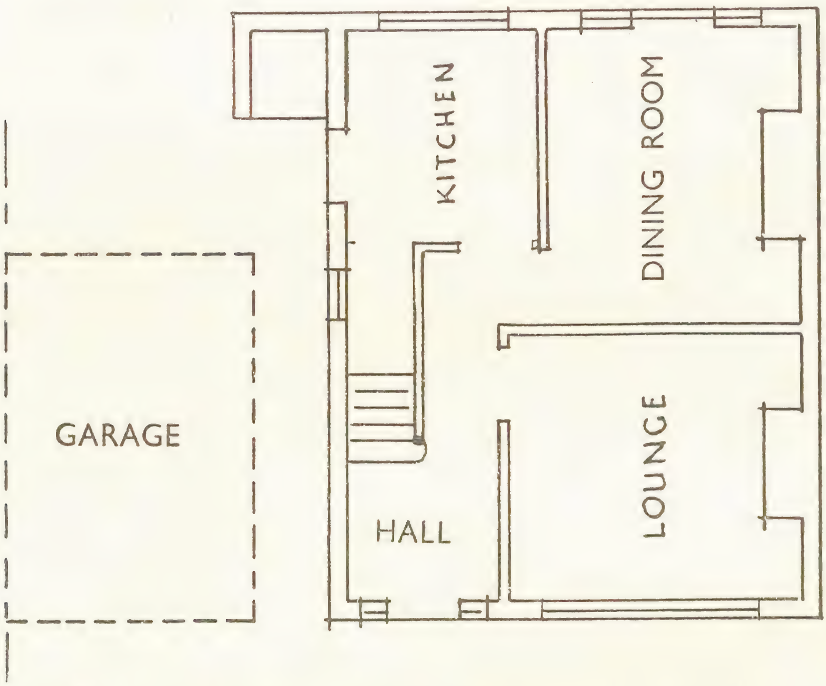


Fig. 3.—Small house plan. A common type, compact but cramped.

In this plan the scullery is omitted, and as the kitchen is usually small, the working quarters of the house are inadequate.

An improvement to this type of plan is illustrated in Fig. 4. There is one living room with a dining recess at the back. This can be partitioned off if required. The kitchen is larger, and there is a covered yard which can be used for washing. The garage projects at the front, but the overall width of the house is no greater than that shown in Fig. 3.

Such houses as these have their plans dictated and stereotyped by timid conventions and severe cost restrictions. We must turn to the individually planned house costing from £1,000 upwards for an opportunity to plan and equip in accordance with modern requirements and opportunities.

The New Planning.—As a comparison between old and new methods of planning, we may compare Figs. 5 and 6. In Fig. 5 we have a small

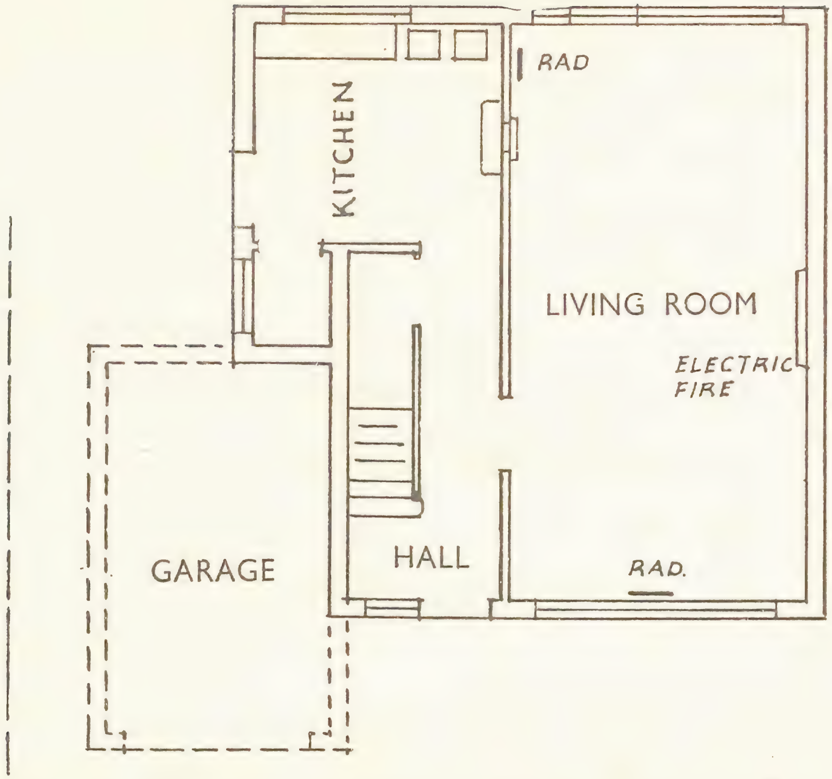


Fig. 4.—Small house plan with one spacious living room. Compare with Fig. 3.

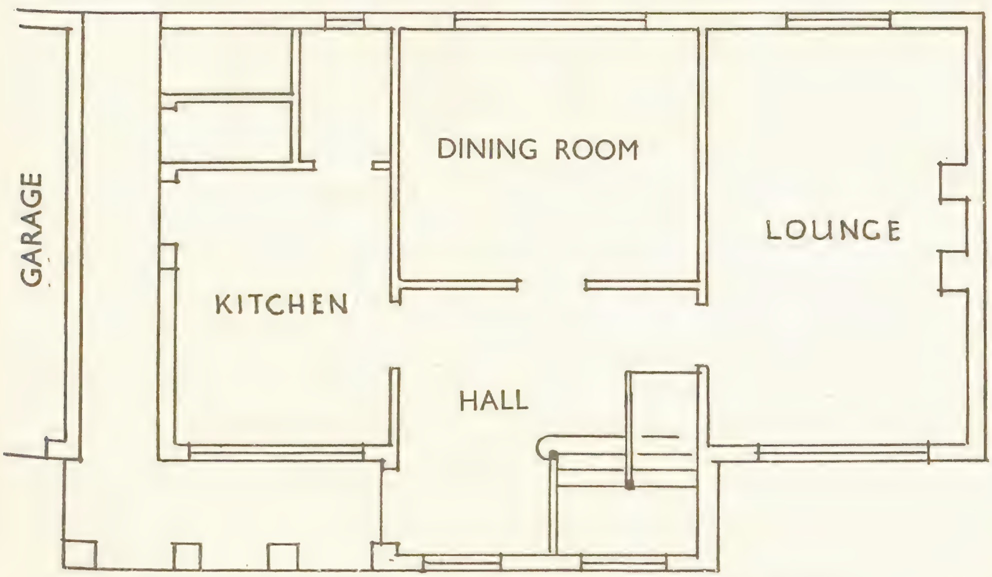


Fig. 5.—Plan of detached house with separate rooms for each function.

detached house on a fairly wide site. It is a typical example of what was considered good planning only a few years ago, and is still satisfactory to many people. We may call this segregated house planning. That is, there is a separate room for each function : dining room and living room are separate. There is no direct communication between kitchen and dining room. There are no built-in fittings. A number of rooms are provided, and the furniture is merely placed wherever it fits best, and in many cases it is a misfit rather than a fit.

In Fig. 6 we have a house of about the same size and plan shape, but planned on entirely different lines. We may call this open planning. In

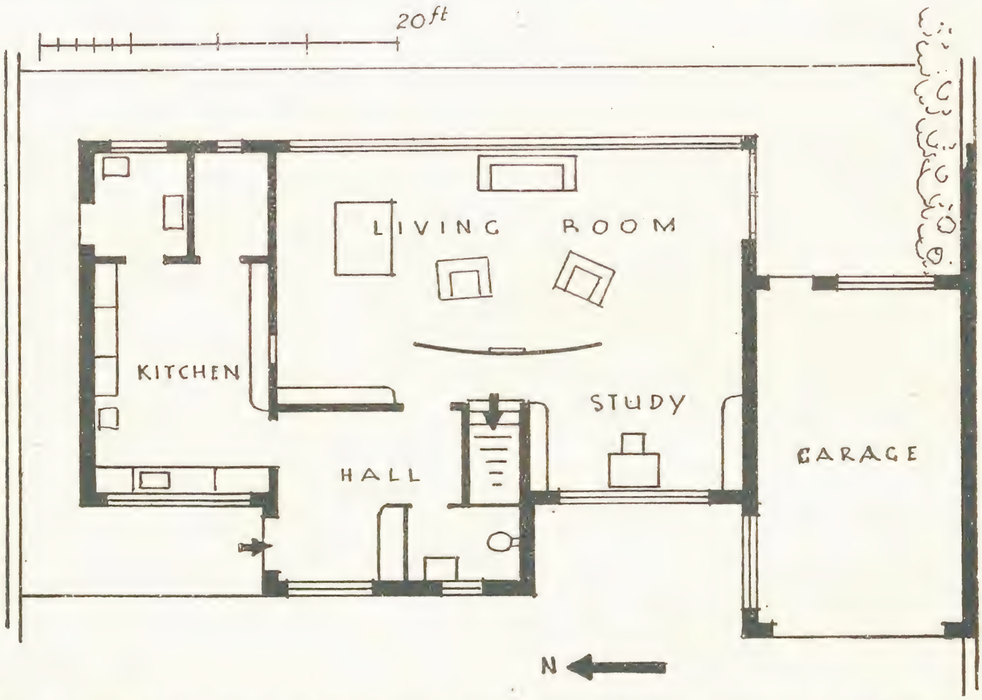


Fig. 6.—Plan of detached house with dining, lounge and study space combined in one large room.

one large room we combine dining, living and study space, yet for each function there is an appropriate location. The dining space is near the serving hatch and fixed sideboard. The study space is recessed and flanked by built-in bookcases. The staircase leads directly from the back of the living space, from which it is shielded by a curved screen. An electric fire is fixed to the concave side of this screen.

For the small family such an open plan has advantages. First, it gives a pleasant spaciousness. Second, it is easy to use, both for work and recreation. Third, it is comfortable. You don't have to open doors or pass from a warm room to a cold one.

People who live in such modern openly planned houses speak enthusiastically about the freedom of movement, the abundance of open floor

Fig. 7.—House of traditional design, showing plans, elevation and section.

space, the lightness and open views, while almost everyone is only too familiar with the cramped, box-like, uncomfortably small rooms, the irritating opening and closing of doors, and the ill-fitting furniture, between which one must step with care, of the segregated plan.

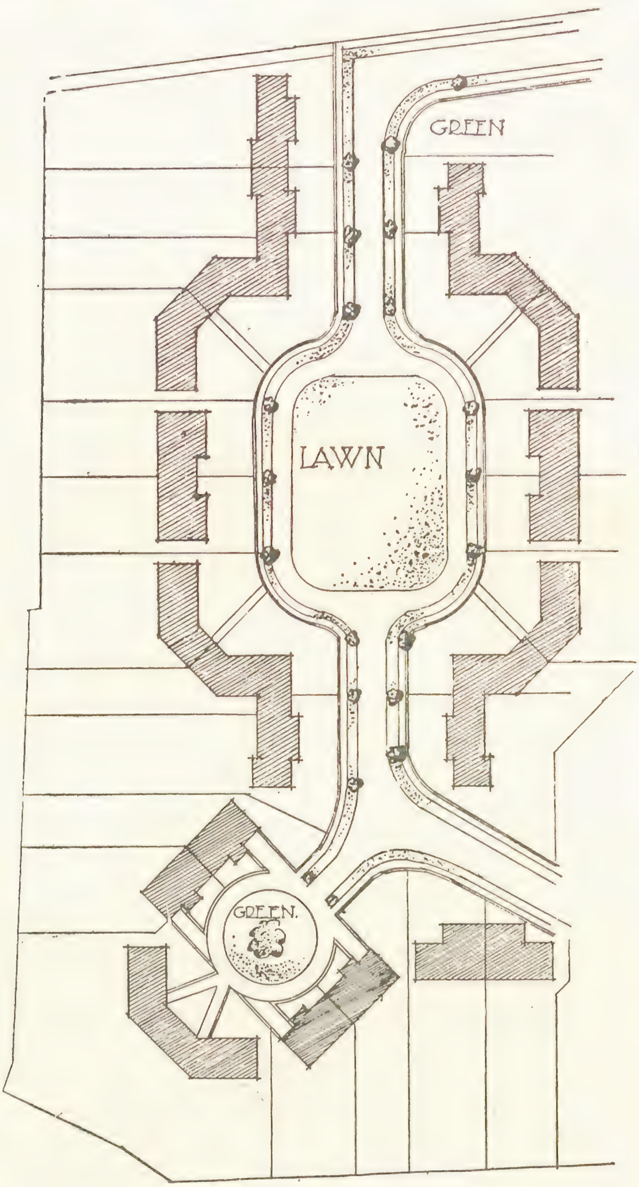


Fig. 8.—Typical housing layout.

It will be noticed, too, that in the open plan the rooms are planned round the furniture and the kitchen is planned round the essential fittings. The kitchen, by the way, is big enough to use as a breakfast room for two or three people. And a well-fitted modern kitchen is quite an agreeable room to eat in.

Such a house should have central heating with auxiliary electric or gas fires. No open fireplaces (if electricity or gas is available), and the kitchen should be well equipped with refrigerator, built-in flush-faced cupboards and stainless-steel sink.

It is not suggested that the plan shown in Fig. 6 would suit every family. With a large family it would be very useful to have a second room for occasions when one member requires absolute privacy.

This demand for occasional segregation can be met by having a portion of the combined living space partitioned off by a sliding or folding partition. A rubber track may be used for this purpose, which with ball-bearing fittings gives easy and silent working.

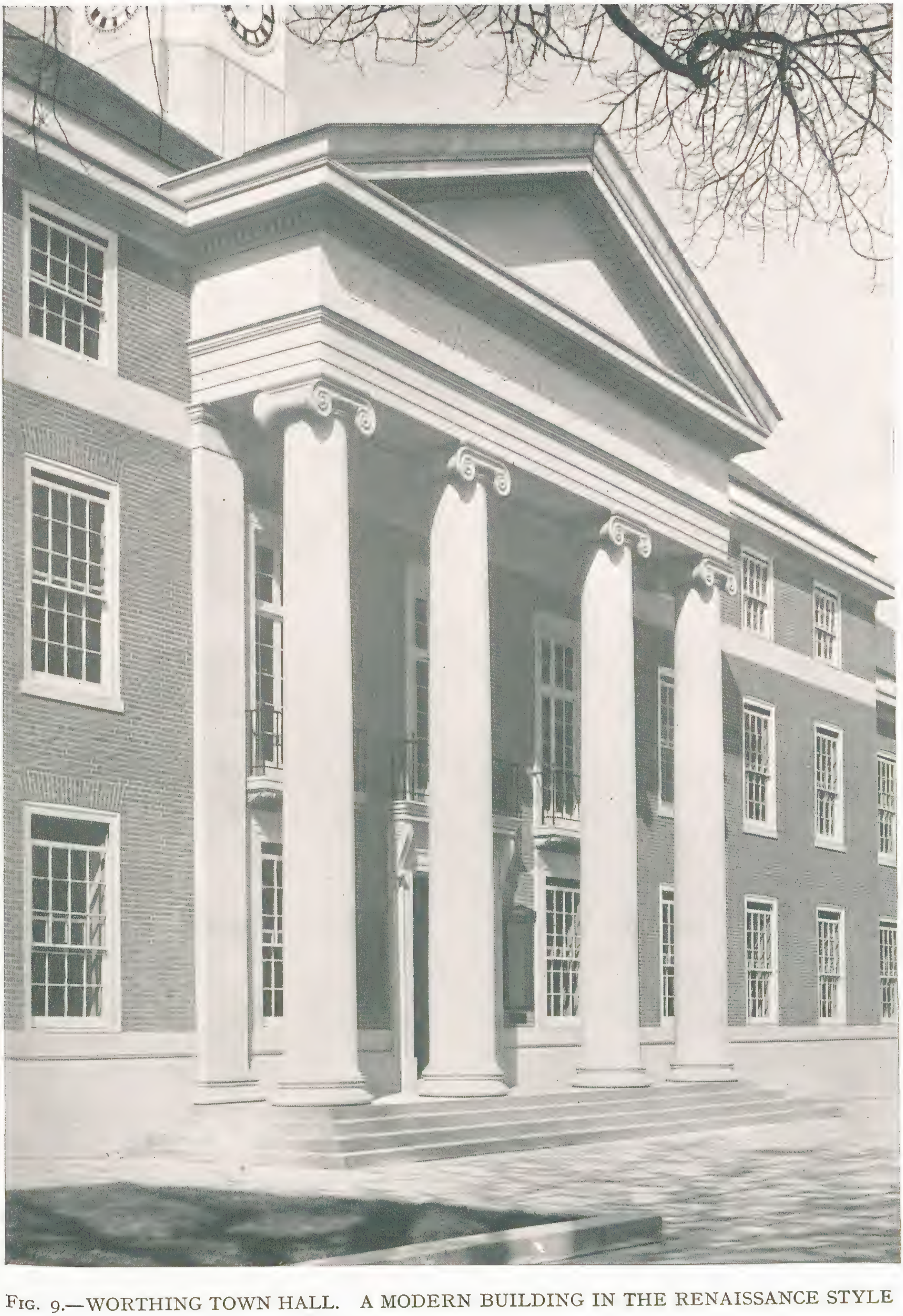


Fig. 9.—WORTHING TOWN HALL. A MODERN BUILDING IN THE RENAISSANCE STYLE
(The Empire Stone Co. Ltd.)

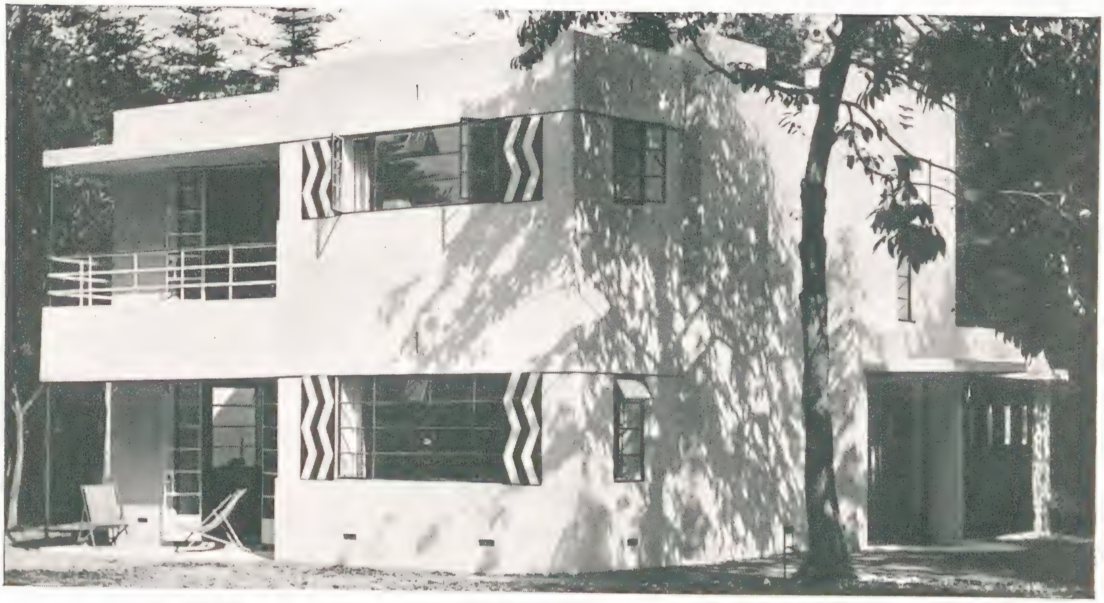


FIG. 10.—A SMALL COUNTRY HOUSE DESIGNED ON MODERN LINES.

The walls are 11-in. hollow brick, cement rendered; the hood over the entrance door is of reinforced concrete on a cantilevered steel frame; that over the balcony on the south front is also in reinforced concrete, supported at one end by a $2\frac{1}{2}$-in. steel column. Steel windows are used throughout, and the flat roof is covered with asphalt. Exterior walls are tinted cream, doors and windows painted in orange and picked out in warm ivory, while the verandah and balcony have bright red columns and railings of cerulean blue. The general colour scheme of orange and ivory is carried out internally, all fittings being in chromium. Architect: W. F. Tuthill.

Bedrooms.—In a small house the bedrooms are planned round the staircase in such a way that landing space is reduced to the minimum necessary to give access to the rooms. For this reason a fairly central position for the staircase is necessary.

A boxroom is desirable in even the smallest house. Wardrobes built into recesses are convenient, especially in small bedrooms, as they leave the limited floor space clear for placing the bed in the best position.

In a well-fitted house the bedrooms should have lavatory basins with hot and cold running water. Even in a small house the principal bedroom should be so fitted.

Built-in gas or electric fires are obviously much more convenient in

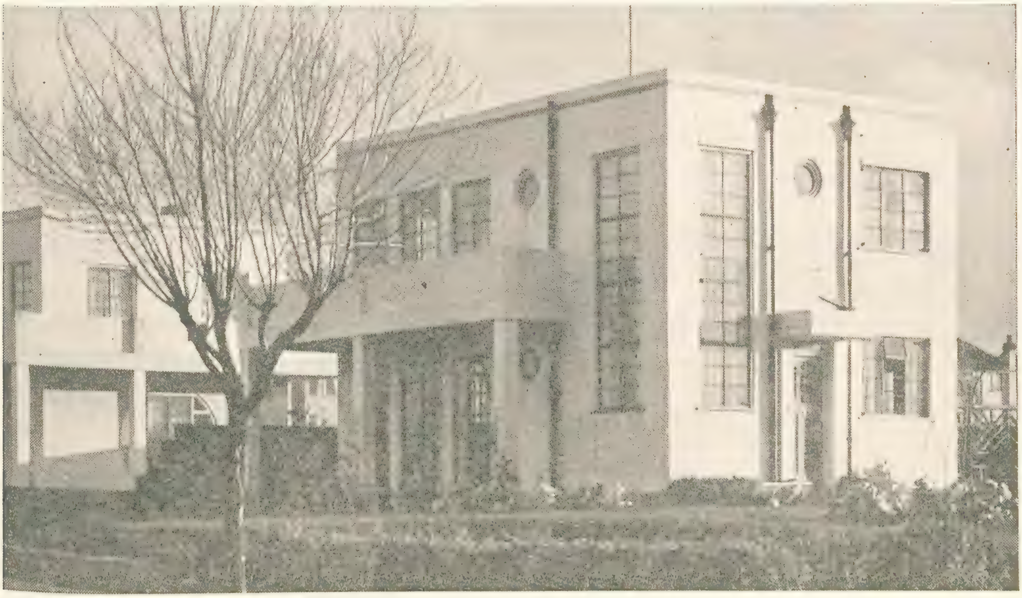


Fig. 11.—Modern concrete house with flat roof.

bedrooms than open coal fires. The gas or electric fires should be auxiliary to central heating.

The bathroom should be at least 7 feet 6 inches × 6 feet, with a separate w.c. In small houses the bathroom is often inconveniently small and a separate w.c. is not provided. The airing cupboard is usually placed in the bathroom, but it is more convenient if the airing cupboard door opens on the landing.

In houses with six bedrooms or more it is advisable to have two bathrooms. One bathroom should be a private bathroom directly attached to the principal bedroom.

Sun Roof and Sun Balcony.—Flat-roofed houses may have paved roofs with a balustrade. They can be used as sun roofs or roof gardens. This is a pleasant amenity, provided there is reasonable privacy and the

roof is not overlooked. This may be arranged by building a high solid balustrade along three sides with an open balustrade facing the garden.

A sun balcony on the same level as the bedrooms is perhaps even more useful. It is especially appreciated when anyone is recovering from an illness and can sit out on the balcony. A southerly aspect is, of course, necessary.

Compact and Open Planning.—Compactness in planning a house is often dictated by cost and site restrictions. But it is not necessarily a virtue in itself. A house of medium or large size on a site of generous dimensions is better if the plan is open, by which is meant extending the plan so that light and air can be obtained from two opposite sides. This gives greater privacy, better sound insulation, and a wider choice of aspects for lighting and views. It is, however, a more costly type of plan than the compact, as there is a greater area of outside walling.

FACTORIES

In addition to the preliminary site considerations already mentioned, factory planning depends on the following factors:

(1) Floor area and accommodation required in relation to site area.
(2) Internal transport of goods in process of manufacture.
(3) Access for external transport (delivery and dispatch).
(4) Requirements of the Factories Act (H.M. Stationery Office, price 2*s.* 6*d.* net). The first four sections deal with design.

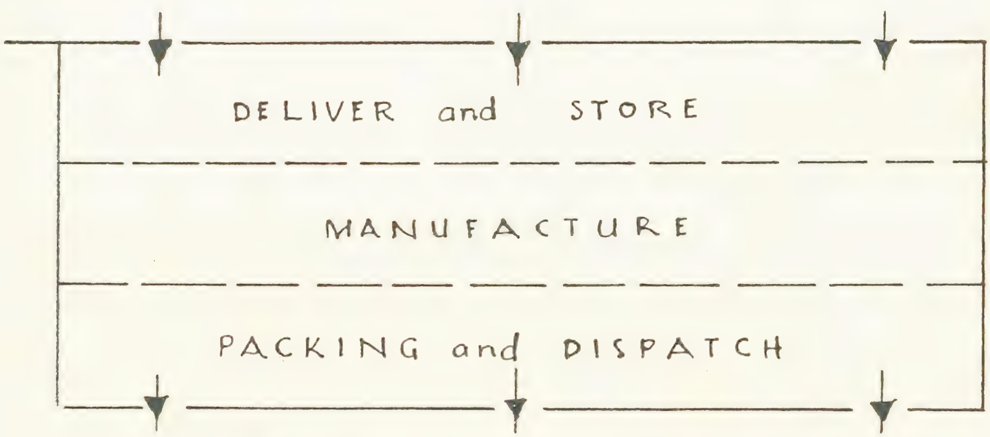


Fig. 12.—Diagram of factory with doorways on long sides.

In addition, the Home Office issue important pamphlets dealing with such subjects as Canteens, Ventilation, Lighting, Seating, Sanitary Accommodation and Cloakrooms, and Fire Protection.

(5) Type of construction proposed in relation to building by-laws.
(6) Special fire risks in relation to fire-office regulations.

It is impossible even to outline the many factors involved. They vary with the site and purpose of the factory, and it is intended here to deal only with general principles governing the design of small factories.

One-floor Factories.—In the modern factory it is usual to carry on the general manufacture of the goods on one floor provided the site gives sufficient area. The factory is not divided in partitioned portions in each of which one type of operation is carried out. This was formerly the case, but it has been found that open planning (already mentioned in connection with houses) makes for more efficient working and enables a continuous flow of material and goods during the various processes.

As far as possible mass production in a continuous production line is followed, and this, of course, calls for open planning.

The principle is illustrated in Figs. 12 and 13. In Fig. 12 the plan is arranged for cross working. The raw material enters at one side, on which there are delivery docks and stores. It passes through the machine shop and the finished goods are packed, stored and dispatched on the other side. This is suitable for the production of simple goods in which the production line is short.

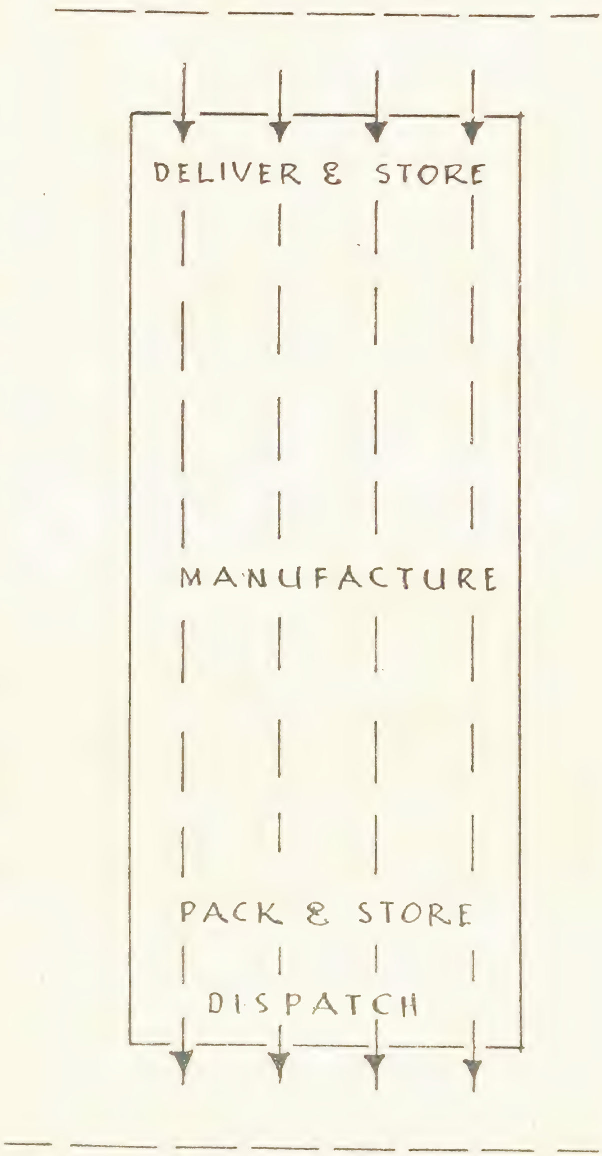


Fig. 13.—Diagram of factory with doorways on short sides.

For the manufacture of complicated goods requiring a long production line the type of plan shown in Fig. 13 is much better. Here the raw material enters at one end, passes through stores to the long machine shop and the finished goods are dispatched at the other end

The length of such a factory is often dictated by the required length of the production line, plus space required for delivery, storage and dispatch. In fact, the factory should be planned around the production line and the machines it contains. This, of course, is only possible on a site of adequate size.

Obviously such sites can be found only in urban and rural districts,

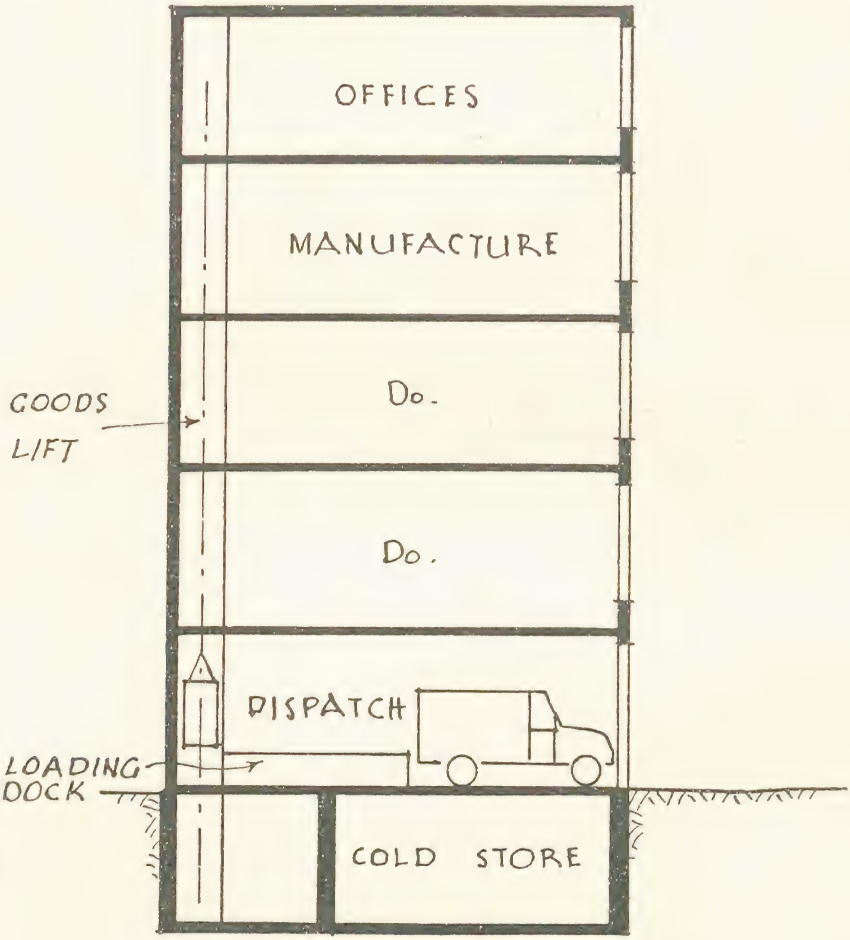


Fig. 14.—Cross section of food factory for a town site.

which is one reason why factory centres are moving away from the big towns.

There is room for lighter industries only in big towns, and the size of the site is not usually sufficient for one-floor production. Five or six superimposed floors may be required to provide the necessary area, so that we then have a factory on the lines of the cross section shown in Fig. 14. Here the raw material is delivered at ground-floor level, transported to the upper production floors by lifts or conveyors, and the

finished goods are then brought down to floor level and stored near the dispatch docks.

It will be noticed that provision is made on the ground floor for lorries to drive in. The delivery and dispatch docks are raised platforms level with the lorry floor.

The offices may be on the top floor, unless there is sufficient space on the ground floor. The basement may be used for special purposes, such as refrigeration.

Accommodation for Workers.—In certain industries the machinery takes up only small space, and the minimum space required per worker is the chief factor in planning.

The Factories Act requires a minimum space per person employed in the room of 400 cubic feet, and in calculating this space no portion of the room more than 14 feet from the floor is to be taken into account. As instances of how this works out: a room 10 feet high requires 40 square feet of floor area per person, and a room 14 feet high requires 29 square feet. The latter figure applies to rooms of all heights from 14 feet upwards.

Sanitary Accommodation.—The following minimum accommodation is required by the Factories Act:

(*a*) One sanitary convenience for every 25 females.

(*b*) One sanitary convenience for every 25 males, except that where more than 100 males are employed or in attendance and sufficient urinal accommodation is provided, then one convenience is required for every 25 males up to the first 100 and one for every 40 after the first 100.

The Act lays down requirements for planning sanitary accommodation, the chief of which is that the conveniences must be separated from the workrooms by open air or a ventilated space, and proper screening of the interior is required.

Daylight.—The positions of windows and roof lights affect the planning of the factory. It is usually desirable to reduce pier and column widths between windows to a minimum to give the maximum glass area along the outer walls. The height of the sill should be as low as possible consistent with practical requirements. For instance, in an engineering shop it may be necessary to keep the sill 4 feet or more from the floor to prevent damage to the windows.

For one-floor factories the north-light roof is extensively used. This is the only aspect from which direct sunlight can be excluded. Direct sunlight on the working plane is, of course, undesirable, as it strains the eyes. The heat from direct sunrays is also undesirable, though for windows or roof lights facing a southerly aspect heat-absorbing glass may be used (see Chapter 8, Vol. IV).

Instead of the saw-tooth-shaped north-light roof, a roof truss of symmetrical frame design with a vertical extension on the north side can be used. This extension has a vertical light fitted.

Clear Floor Space.—In some factories it is no disadvantage to have lines of columns in the interior. But for many purposes this would be a disadvantage, as it restricts the choice of positions for machines and interrupts the movement of heavy or bulky products.

Generally, it is cheaper in first cost to have short spans than long ones, but convenience of working is the prime consideration. This must be looked into and a reasonable compromise decided upon.

Where large floor areas have to be covered with north-light roofs, the trusses can have lines of columns to each bay, or they may take the form of lattice or boom roofs spanning the complete width of the building without intermediate columns (Chapter 5, see Vol. II).

Floor loadings on upper floors affect the design, as the size and spacing of beams and columns depends upon the loads. This is also an important factor in the cost of the building. Where heavy machinery or stores have to be carried, it is generally cheaper to have a one-floor building, so that all such loads are transmitted direct to the ground.

SCHOOLS AND HOSPITALS

The principles of planning these buildings can be only briefly mentioned here. They both give striking proof of the great progress made in planning and design on a functional basis. The school and hospital of fifty years ago, and even less, were gloomy and inefficient, and the fact that they were very solidly built has turned out to be a misfortune. They were built to last, so we go on using them, although by modern standards they are hopelessly inefficient.

Schools.—The chief factor in planning is to obtain an easterly or westerly aspect for the classrooms. Art rooms and technical training rooms should have a northerly aspect, unless special arrangements are made to shield the working planes from the sun.

The assembly hall should be centrally placed, as in the plans Figs. 15 and 16. Fig. 15 illustrates a plan of the quadrangular type, the classrooms being placed on the outsides and the assembly hall in the interior. This is a good plan for a large school on a site of comparatively restricted dimensions. The quadrangles should be of generous size.

In modern planning a more open type of plan is favoured, such as the Z plan in Fig. 16. An open plan gives free access to light and air, and better sound insulation. It is also suitable for standardised construction in a series of plan units, and provision can be made for additional plan units to be added later. Many open-air schools are of this type, the corridors being open and the side of each classroom facing the corridor having folding and sliding glazed " walls," so that in fine weather the whole side can be opened.

The provision of playgrounds and playing fields is an important factor in planning.

The accommodation, and to some extent the design of windows and

other fittings, are governed by the regulations of the Board of Education. In fact the modern school is a type of building planned according to standard regulations rather than to individual requirements.

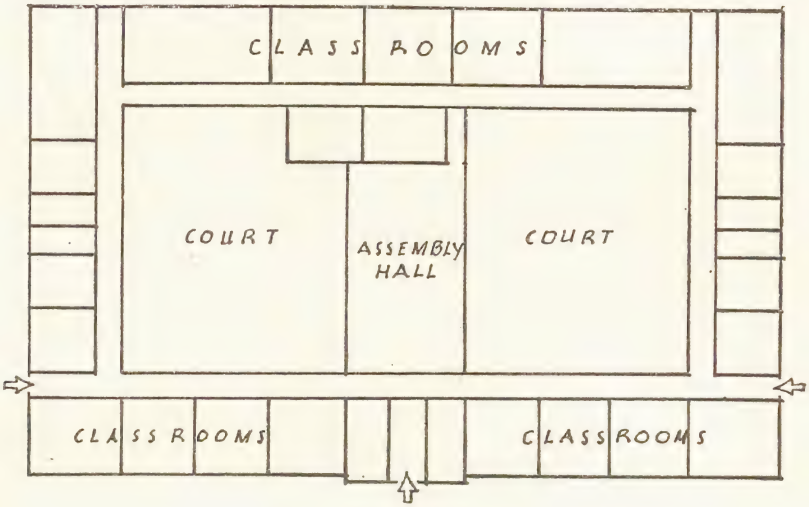


Fig. 15.—School. Quadrangular type.

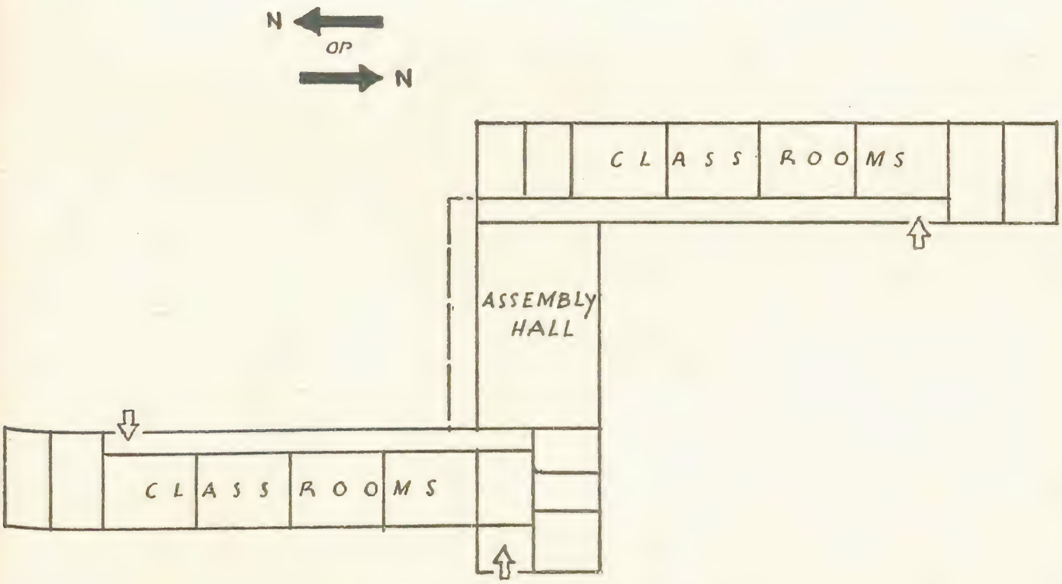


Fig. 16.—School. A modern " open " plan.

Hospitals.—Here again open planning is now favoured for the free access which it gives to light and air. Wards should have east and west aspects, as shown in Fig. 17. In this outline plan it will be seen that there are windows both sides of the wards, and that they give direct sun-

light all day except for a short time at midday. Notice the solarium or sun balcony at the end of each ward. This faces south, and a staircase at the side gives direct access from upper wards to the ground.

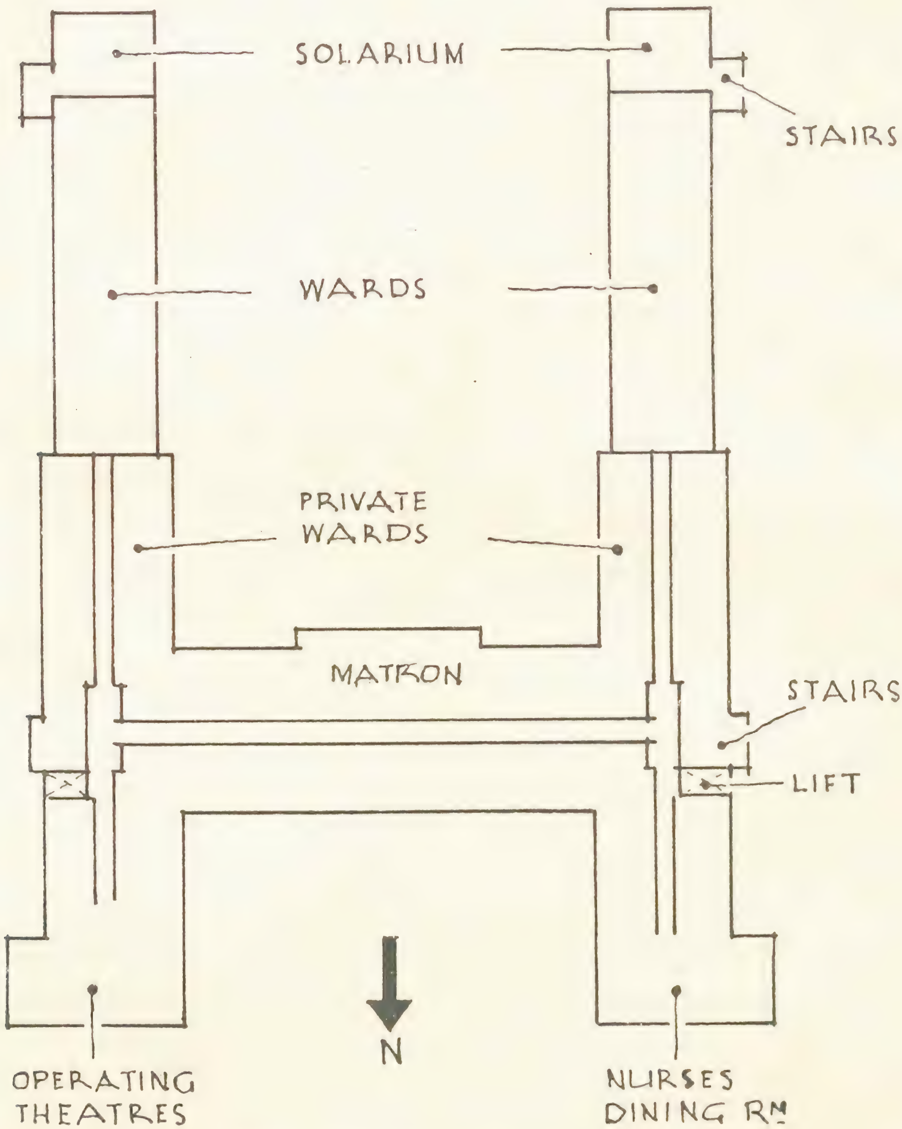


Fig. 17.—Diagram plan of modern hospital.

The operating theatres, nurses' dining room, matron's quarters and other rooms are on the north side, though owing to the open planning windows can be placed to catch the sun where required. The corridors should be noticed, and the positions of lifts and staircases and private wards.

FIG. 18.—LONDON UNIVERSITY.

This is a steel frame building with a "skyscraper" in the centre, but the street elevations are reminiscent of eighteenth-century urban architecture. Charles Holden, Architect.

FIG. 19.—A MODERN STORE.

Steel frame building with stone ashlar facing. The window shapes would be impossible in traditional construction. W. A. Johnson, Architect.

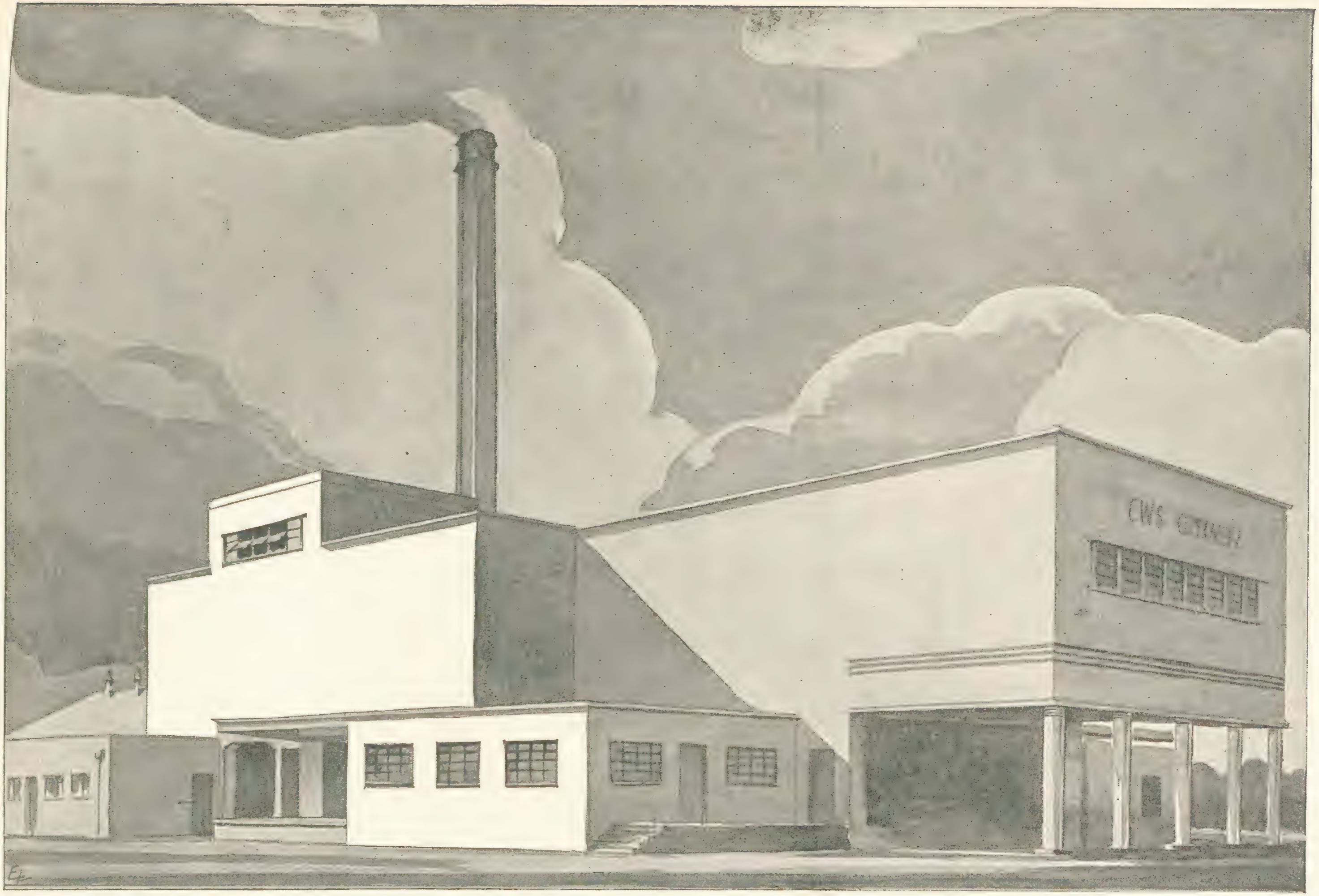


Fig. 20.—A modern dairy. A reinforced-concrete building of well-proportioned cubic shapes. L. G. Ekins, Architect.

ARCHITECTURE

The nature of functional architecture is explained in the beginning of this chapter. A few illustrations are given here. In Fig. 20, a modern dairy for the Co-operative Wholesale Society, we have an example of a

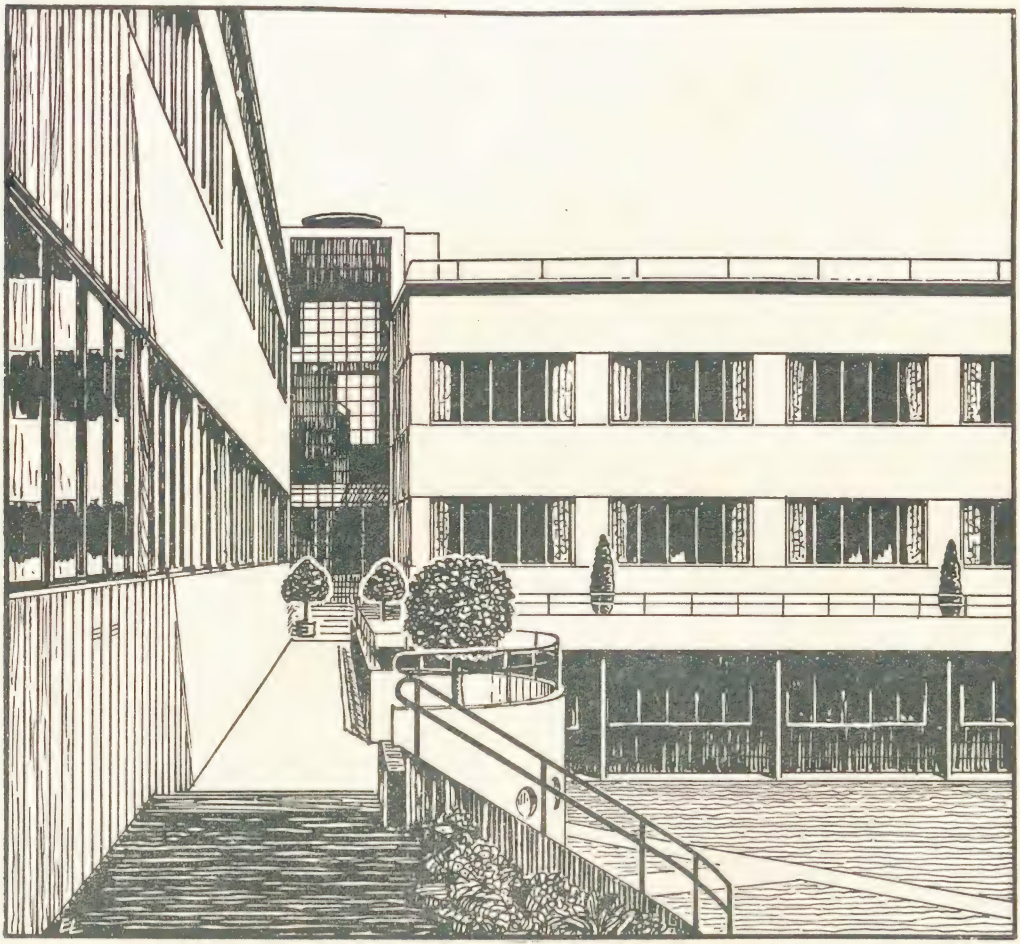


Fig. 21.—Block of flats. A modern concrete building, the appearance arising directly from solution of functional and structural problems. A. V. Pilichowski, Architect.

reinforced-concrete building. It is a simple, well-proportioned arrangement of cubic shapes. A "traditionalist" architect would have concealed the structure and function behind a crudely trimmed "architectural" shell. An engineer would not have achieved the orderly proportions or that pleasing arrangement of the covered loading dock.

Fig. 21 illustrates another concrete building—a block of flats. The firm horizontal lines flow naturally from the wide plain windows. The clean open feeling of this building arises from the direct solution of planning problems.

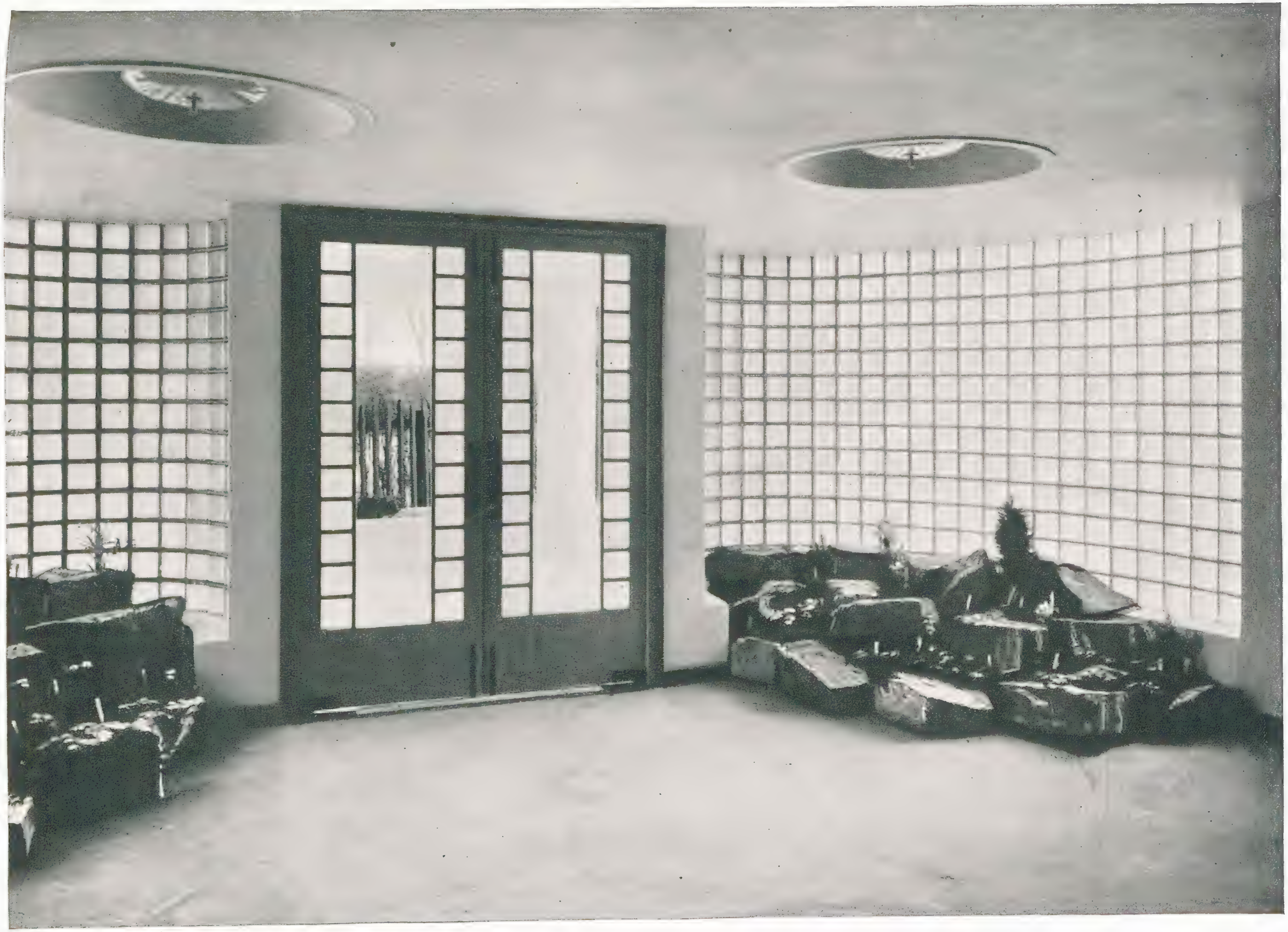


FIG. 22.—A MODERN ENTRANCE HALL WITH GLASS BRICK WALLS.
(Courtesy of Pilkington Bros. Ltd.)

FIG. 23.—BUNGALOWS BUILT OF STANDARDISED FACTORY-PRODUCED WALL, FLOOR, AND ROOF UNITS. The units allow considerable flexibility in design. (Courtesy of Uni-Seco Structures Ltd.)

The new London University illustrated in Fig. 18 is an attempt to provide a modern building which will harmonise with the buildings around it. The street elevations succeed in this, but the central " skyscraper " block is characteristically modern. It illustrates the difficulty of running with the traditionalist hare and at the same time hunting with the modernist hounds, and also the problem of designing large buildings in an old city like London where, though we still like to have a low " skyline," we are sometimes forced to interject a " skyscraper."

The modern store building illustrated in Fig. 19 owes nothing to tradition in planning or architectural design. It is a steel-framed building faced with stone ashlar. The continuous horizontal and vertical windows are obviously possible only in framed construction. The upper part hangs airily over the shop front and yet looks absolutely secure. In this it is a pleasing contrast to shop buildings of traditional design in which the heavy upper part stands on thin stilts or is apparently supported on nothing. In the building illustrated the wide shop windows cover the columns so that there is unobstructed display of the goods.

Fig. 22 shows how a new use of an old material (glass) introduces new characteristics into design. The entrance door is flanked by curved panels of glass bricks, forming walls which admit light but not vision, and have much greater thermal insulation than ordinary windows.

The bungalows illustrated in Fig. 23 are of light prefabricated construction. Walls, roofs, floors and windows are built up of standard factory-produced units. Such buildings can be of pleasing appearance and are flexible in both planning and design.

The drawings at the beginning of this volume illustrate other buildings, some of traditional design and some owing little or nothing to tradition. Careful study should be made of the plans and elevations to see how the function of the building and the structural system affect the appearance. These drawings are good examples of architectural draughtsmanship, in which the architect exactly defines his design, first in general drawings to a small scale (usually $\frac{1}{8}$ inch to 1 foot), and supplements these drawings with details drawn to a larger scale (not less than $\frac{1}{2}$ inch to 1 foot, with intricate details drawn to larger scales or even full size).

CHAPTER 2

SITE PREPARATION AND ORGANISATION

THE factors which should be considered in choosing a site have already been described in Chapter 1. As then stated, it is not always possible to secure an ideal site, and unfortunately it is common for an owner to buy the site before consulting an architect. Both architect and builder may be faced with difficult problems owing to the inherent unsuitability of the site for the type of building.

PRELIMINARIES

When a builder takes over a site he has already before him the architect's building plans and a site plan. He is already familiar with the main features of the site, which he has previously visited for the purpose of tendering. Now that he has to commence the contract, he must have another look round and make notes on the various snags which he has to face at the outset, and the features which will determine the organisation of the contract.

Levels of the site will be required (see Chapter 3) and trial holes must be dug to ascertain the nature of the ground. Even if this work has already been done, it may be necessary to supplement it by a more thorough survey, especially where a large building has to be erected on an awkward site.

Geological Survey.—To ascertain the nature of the subsoil and the possibilities of obtaining water from below the ground, the geological map of the district in which the site is situated should be consulted. On this will be found indicated several "strata" or layers of different soils. These, it has been assumed, were either deposited by the waters which once covered the earth's surface, or were formed during the gradual cooling of the earth's surface. The unevenness and irregularity of these layers is accounted for by the upheaval of the earth's crust during the cooling process, the operation being assisted or delayed by such agencies as heat, volcanic action, and subterranean chemical alterations. In some rocks, such as granite, there will be seen no evidence of stratification, or layering, but a fused surface is presented such as could have been produced only by great heat and pressure—in others, such as slate, the evidence of stratification is clearly evident.

In certain districts, as for instance the cliffs in the neighbourhood of Portland, where the Portland stone is still quarried very largely, the strata are to be very clearly seen demarked almost in the manner of the

pages of a book, the corners of which have been turned up. In a smaller way this outcropping of strata may be seen in deep cuttings to roads and railways.

The Purbeck strata afford an example, perhaps the best, of one of the latest remodellings of the earth's surface. What the actual force was is not known, but it is thought that contraction turned up the strata on edge. The result of this action, whatever its origin, has been that all the geological strata are exposed to view in the cliffs and shores of the Isle of Purbeck, in Dorset. Thus, in a section taken over a distance of less than three miles, the following strata outcrop : Bagshot sand, London clay, chalk, Upper Greensand, Neald clay and Hastings sand, Purbeck beds, Portland stone, and Kimmeridge clay.

The Purbeck beds consist of limestones, shales and sandstones, with clay partings, and are divided into an upper, middle and lower series, in which are to be found alternations of fresh- and salt-water deposits.

In no part of Great Britain are the Oolites more fully represented than here. The Purbeck oolite is itself divided into three series known as Purbeck marble, middle Purbeck, and the Purbeck dirt bed. Purbeck marble, a shelly limestone, is much used in polished stonework, as in churches and for tombstones ; and in the Purbeck dirt bed there are found fossilised trees, upright in their original position, with their natural soil still surrounding them. Near Lulworth Cove, nine distinct sections of the Purbeck strata are to be seen inclining from the horizontal to the vertical.

There is probably scarcely a large town in this country in which Portland stone is not used in the more important public buildings, and yet Portland itself still maintains what would appear to be an inexhaustible supply.

Consequently, from these few notes it will be seen that there is much to be learned with regard to choice of a building site from a slight knowledge of the strata of the subsoils.

Town and Country.—The nature of the preliminary operations will naturally differ considerably on sites in towns from those in the country.

In the former instance, where old buildings already occupy the site of the proposed new building, pulling down or demolition operations will be the first necessity ; whilst in the second instance, it may be that the site will require clearing of tree stumps or standing trees will require to be felled. And though both of these operations are specialised trades, usually sublet, it is advisable that the general contractor should know something of them.

ORGANISATION

Large building contracts now need very efficient organisation, if the problems of speedy construction, inter-relation of sub-contractor's and specialist's work, and general complexity are to be solved. The building contractor may have less than half the constructional work to do, but

he has to consider the other half, and to so organise the job that he does not keep other contractors waiting, and they do not keep him waiting.

A large building contract is supervised directly by a clerk of works representing the architect and employed by the owner. The clerk of works cannot give orders to the contractors or their employees. His job is to watch and to check ; and to measure and agree with the contractors, or their foremen or surveyors, any variations from the contract drawings ordered by the architect. A good clerk of works should have a sound knowledge of construction and organisation, absolute honesty, firmness and tact.

These qualities should also characterise the contractor's foreman. It is essential for the smooth running of the job that clerk of works and foreman work well together. By so doing they anticipate snags, save time, and reduce the work of both contractor and architect.

The General Foreman.—The building contractor employs a general foreman to supervise all trades, organise the site operations from the contractor's angle, requisition material, control labour, and on small jobs to do everything for the contractor which cannot be done in the contractor's office.

The foreman is generally a practical tradesman, usually bricklayer or carpenter, with a talent for organisation, discipline, and sufficient theoretical knowledge to understand drawings, specifications and bills of quantities. On small and medium-size jobs this type of foreman-tradesman is best, especially on buildings with load-bearing walls and traditional construction. On such buildings the foreman-tradesman is capable of exercising general supervision and of solving practical difficulties as they arise. But on very large contracts, with sub-contractors to deal with, and employing many men, ability in organisation and office work is more important than practical experience of building.

The Contractor's Agent.—A new type of general supervisor is now being employed by many contractors. It started in civil engineering, and is spreading to general building. This is the contractor's agent, or engineer-agent as he is called in the civil engineering world. His training background is largely theoretical. He may be a qualified structural engineer or builder, but in addition to an expert knowledge of building construction he must have had good office experience, and above all he must be a first-class organiser.

The agent on a big contract usually has more authority than the average foreman. The whole job is run either by him or through him. The contractor gives all instructions to the agent, who then passes them on to foreman and other executives. The contractor usually leaves the whole organisation to the agent, since the agent should be able to decide on the most efficient and smooth working methods of planning and timing operations. He is the man on the spot, and, like a general on the battlefield, he expects headquarters to back him up and supply him with his needs.

Site Staff.—On a very large contract the contractor's agent has an office staff: cashier, wages clerk, labour controller, time-keeper, and perhaps a surveyor.

A general foreman of the practical type is often employed under the agent's control, or the agent may supervise a number of specialist foremen or charge hands.

The general organisation of a builder's business and the relationship between architect, owner and contractor is described in Chapter 10, Volume IV. We may now consider the various site operations which commence when the contractor takes over the site.

Preliminaries.—The contract should be organised from the start, and this should be done in consultation with all concerned. Architect, main and sub-contractors should consult together so that the sequence of operations can be planned, and a time and progress schedule or chart prepared.

The chief items to be considered in organising the contract and preparing the site are:

(1) Preparation of time and progress schedule or chart in consultation with the architect and clerk of works.

(2) Erection of hoardings and fans, and obtaining permits.

(3) Preparation of any necessary approach roads.

(4) Demolition of any existing buildings.

(5) Shoring and tying adjoining buildings.

(6) Erection of offices for site staff, clerk of works, etc.

(7) Consideration of the general site problem, including any special features such as measures to enable part of an existing building to remain in use during alterations or rebuilding, with the erection of temporary partitions, doorways, etc.

(8) Excavating, levelling and sub-structure: taking up or diverting drains.

DEMOLITION

Demolition is a skilled trade in itself tackled proficiently only by demolition contractors.

Skilled men are required chiefly because little or no scaffolding is ever used, thereby causing a risk which the ordinary builders' labourer is not capable of undertaking. The whole of the materials are salved for purposes and uses of every description, and only experienced men can salve these at the least amount of costs to his employer. Insurance risks are very heavy.

The costs of demolition work have a bearing on it being a classified trade, in view of occasions when sites are cleared of thousands of tons of debris and materials which have to be and are in most cases executed at very low rate, which comes about in the following manner. The respective contractors when tendering usually have outlets for the disposing of all the old materials, and if the demand is plentiful, the costs of

dismantling and removal are governed by such demand; when the channels for disposal are bad, this increases the costs of clearance.

The channels for the disposal of the old materials are numerous. The old bricks of a sound nature are usually cleaned of the old mortar, and reused in new erections; the hardcore and rough bricks are usually carted to the sites of new roads, or crushed into broken brick of varying sizes for concrete reinforced floors, etc.; the brick rubbish is carted to mills for recrushing and mixed with fresh materials, and then reground into mortar for use in housing schemes, etc.; the best of the timber is reused for all purposes, and the obsolete timber is taken to firewood cutting and bundling mills and from there is served out for daily needs; the slates and tiles taken from the roofs are selected and resold for repairing roofs, and many of the slates are often used for dampcourses in new erections. Nothing is wasted. and for this reason a demolition contractor must have a large clientele before whom he can place his accumulations of many thousands of tons each year. Again, he must have large depots and dumps to handle and store the many tons of materials which cannot be disposed of immediately, and must have a fleet of vehicles capable of removing all weights and every description of materials in the shortest period of time.

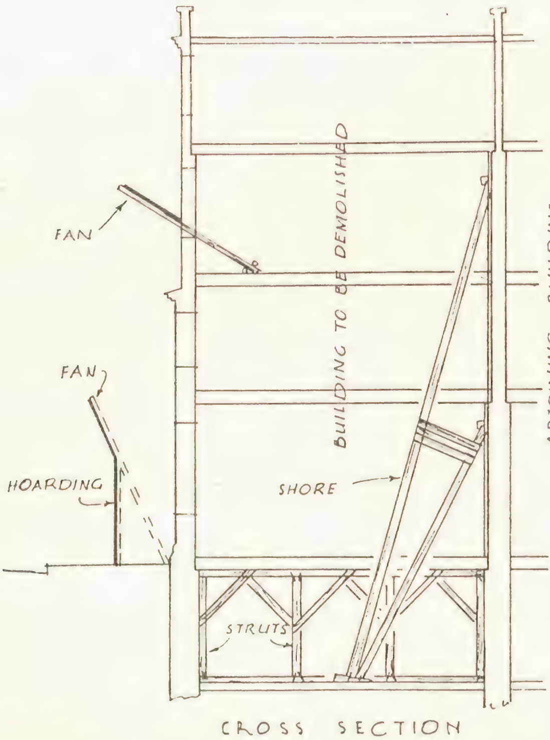


Fig. 24.—Preparation of building for demolition.

It is experience that enables the demolition contractor to be able to estimate the value of the old materials to enable him to give the satisfactory credit that the architect or builder generally requests.

There are many delicate points to be considered in the execution of the work, and great difficulties which, though previously unforeseen, very often crop up, have to be overcome. It is here that demolition becomes the work of a specialist. Space is nearly always limited, and it is sometimes impossible to demolish buildings in a simple manner where basements, etc., exist.

Methods of Demolition.—The buildings and environment should be carefully considered in deciding the method. Care must be taken to

leave adequate support for any adjoining buildings. This may be done by:

(*a*) Leaving certain walls standing. If possible, any basement walls should be left, as these act as shores to the adjoining building.

(*b*) Erecting shores to provide temporary support to the adjoining building. These should be erected before the demolition commences. They must be placed inside the building to be demolished, and for this purpose it will be necessary to cut into the walls and floors to some extent.

Strengthening the adjoining building with steel tie rods and plates is generally preferable to shoring, but if the building is in separate ownership it is usually difficult to obtain permission.

There are two methods of demolition.

(1) Taking the building down by hand, starting at the top. If the salvage value is high, great care is necessary, and much of the material must be lowered by tackle rigged on sheer legs or by hoist equipment. If the salvage value is not high, the walls may be knocked down in large pieces, using picks and wrecking bars. With wood joist and boarded floors, the floor boards may be removed and the debris thrown inwards so that it falls to the ground floor.

If there is a basement, the ground floor should be strutted, so that it can act as a platform to hold the debris, which is then easy to remove.

(2) Taking the building down by collapsing supports or by using explosives. These methods can only be used where there is plenty of space around the building, and no danger to passers-by or to adjoining buildings. Great care is necessary to avoid injury to the workmen.

If supporting walls and piers are partly cut out, the remainder may be removed by attaching wire ropes to the wall or pier at one end, and to a heavy lorry at the other. The lorry can then be driven ahead to pull the wall or pier away, thus collapsing the structure above. A rocket device is made which projects a cable over any high part of the building which may be out of reach.

Alternatively, explosives can be attached to walls and piers. The charges can be detonated electrically from a safe distance. Destruction of the lower supports by this means will collapse the structure above. Such methods should be used only by experienced demolition contractors.

Sorting.—To obtain the maximum salvage value, the building should be carefully demolished by hand. Sound tiles and slates should be taken off, lowered to the ground and stacked. Lead, zinc and copper roofing has a good salvage value as scrap metal. It is usually convenient to roll it, but there is no need to avoid damaging the sheets.

Good-quality facing bricks have high salvage value. If in lime mortar, they are quite easily separated and dressed to make them fit for reuse, but if in strong cement mortar it is a difficult and costly job to separate and dress.

Old sanitary fittings and heating equipment have little more than scrap value, but modern fittings should be taken out before general

demolition commences. In some old buildings the fireplaces, panelling, etc., may have a high value, especially if they belong to the great architectural periods of the sixteenth, seventeenth and eighteenth centuries.

Another point of importance is the shoring up of adjacent buildings, and although prescribed by respective district surveyors in some localities, it is generally left by the architect or builder to the discretion of the demolition contractor whether and where this is necessary, especially as he is responsible for all damage that may possibly occur.

A demolition contractor must be in a position to carry out work large or small at a moment's notice, and to execute the same continuously without a stop, for example:

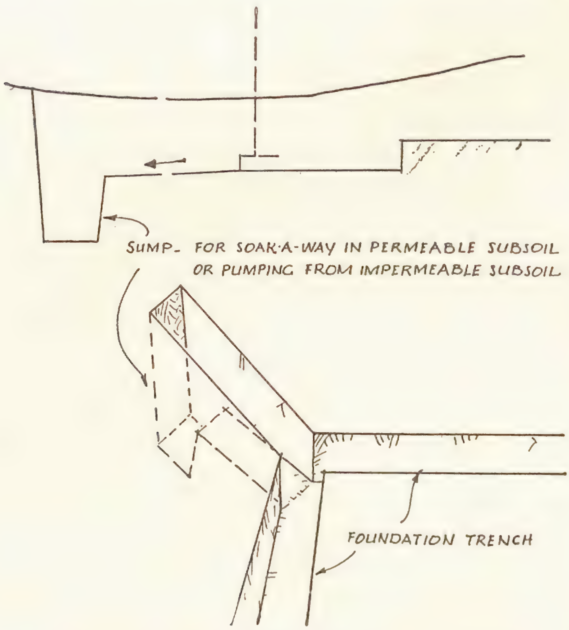


Fig. 25.—Temporary drainage of foundations.

A chimney shaft which was disused for several years existed in a warehouse, occupying in the ground floor a space of approximately 150 feet super. The valuable space taken up by this shaft was required, and it was decided to have the shaft removed. The shaft projected up through the roof of the building, and there were difficulties to be overcome. In the building several machines were in use day and night, and a considerable number of employees were employed in the warehouse; the only period that could be allowed the demolition contractor to pull down and clear away this huge shaft, which necessitated the removal of several hundred tons of brick and ironwork, was one week-end, *viz.* 12 noon Saturday to 5 a.m. on the Monday. The shaft could not be felled, so it had to be knocked down brick by brick inside its own space. There was no time for erection of scaffold, and care had to be taken that none of the surrounding roof was damaged. The work was executed and completed without any damage several hours before time.

A great assistance to the demolition contractor at the present time is the oxy-acetylene cutting plant. On many occasions compound and other girders are encountered in buildings; these are heavy, and for various reasons no cranes can be fixed to remove them. Before the discovery of the cutting plant these compound girders were a considerable worry to the housebreaker, but now, with the aid of the cutting plant, it

is possible to cut the obsolete girders into man-handling sizes at comparatively low cost ; the residue is sold as scrap for remelting.

ACCESS TO SITES

In both town and country the access to sites is a matter of first importance, having a very definite effect upon the ultimate cost of the contract.

On a town site which is to be entirely occupied by the building, the stacking of materials often requires careful consideration, as these must be stacked within the building, and the entrance to the operations must be arranged for conveniently with this in mind. Though materials may not be stacked outside the boundary of the site, it is permitted by the by-laws that they be stacked on properly constructed stagings as are described in detail later. Any position chosen for stacking materials should be conveniently situated with regard to hoists. The actual position chosen will depend upon the plan of the building to be erected ; but a central point is generally most serviceable in the space to be occupied either by an internal light well or a staircase.

Country Sites.—Here the matter of access does not present a problem so difficult of solution. However, if a driveway or road is included in the contract, it will be advisable to excavate for this before any carting is begun, and to fill in with hardcore, leaving the surfacing to be completed at the termination of the contract.

The foundation of a road or driveway is the most important part of the work in connection with its formation, as upon its satisfactory construction depends its stability and resistance to heavy loads which tend to cause subsidence. Such subsidence is a very difficult defect to cure once a road is laid, but can be prevented by the use of suitable materials and construction. The extent and nature of these will depend to a great extent upon the character of the subsoil. The first necessary operation, in any event, is the excavation of the top soil to whatever depth is necessary to reach the subsoil. Bore-holes, sunk at the time of estimating, to ascertain the nature of the subsoil, are a wise precaution, which may save considerable loss due to under-estimation of the extent of the excavation later found to be required. This top soil or loam, if suitable, should be carted or barrowed to points convenient for its use in the making of the garden, concerning which the instructions of the owner should be obtained.

Where the subsoil is rock, very little else will be required beyond the removal of the top soil ; though even with rock, there should be a layer of broken rock, of more or less homogeneous consistency, spread over the excavated area. This will prevent the covering layers working through from projecting rocks below and eventually causing bumps in the road or driveway.

DRAINAGE OF SUBSOIL WATER

For the preparation of a garden, the soil should be trenched to a depth of 3 feet, where the nature of the subsoil will permit of this. It is obviously no use trying to dig up a rocky subsoil or a callust.

To ensure proper workmanship, the method employed is to dig out the soil from a trench at one end of the area to be trenched and to barrow the soil to the other end. The bottom spit is then turned over with either the spade or the fork and returned into the bottom of the trench. The top spit, followed by the second spit of the next digging, are then dug and thrown into the trench first dug. All roots and large-rooted weeds, wire grass, etc., should be removed and burned during this operation. It is a fallacy that stones should be collected unless the soil is more stones than anything else, as stones hold the moisture in the soil and are therefore beneficial.

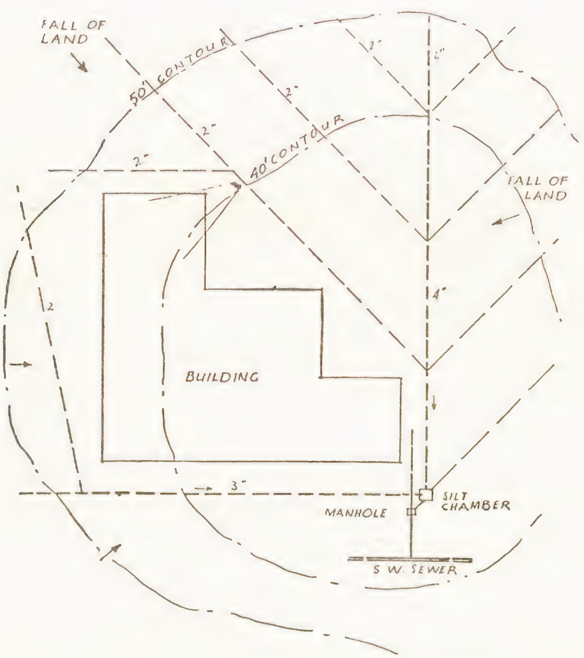


Fig. 26.—Plan of typical subsoil drainage.

When the foundations of the house have been pegged out on the site, it will save considerable after-work, and where the site is a damp one, considerable pumping or baling of trenches, if the matter of subsoil drainage of the whole site be taken in hand before anything else is done.

Springs.—Should there be an actual spring on the site—and springs are by no means an unknown occurrence, even on sites in cities—the water from this will require special treatment as distinct from that usually known as subsoil water. On several of the sites in the West End of London, on which new buildings had deep excavations for basements and sub-basements, continuously flowing water was encountered which proved to be that of an underground river. In such an instance as this, it is obviously no use trying to get rid of the water by pumping, nor can it be dammed back. The only course left is to pass it on in the direction of its natural outlet. This, in fact, was the course adopted on several sites in the Haymarket, the water being led round the foundations and eventually given issue into the Thames.

Though actual springs may be a comparatively rare occurrence, yet

Fig. 27.—A RUSTON-BUCYRUS 10-RB ⅜-CUBIC YARD SKIMMER ENGAGED ON SITE CLEARANCE.

Fig. 28.—A RUSTON-BUCYRUS 19-RB ⅝-CUBIC YARD SHOVEL CUTTING A NEW ROAD THROUGH LIMESTONE. A RUSTON-BUCYRUS 10-RB ⅜-CUBIC YARD DRAGLINE SEEN IN BACKGROUND IS REMOVING THE TOP LOAM.

Fig. 29.—A RUSTON-BUCYRUS 10-RB ⅜-CUBIC YARD SKIMMER LEVELLING THE GROUND FOR A HOUSING ESTATE.

(All photos by courtesy of Ruston-Bucyrus Ltd.)

FIG. 30.—A NEWTON-CHAMBERS SHOVEL EXCAVATOR AT WORK.

FIG. 31.—SURFACE-SKIMMING WITH A NEWTON-CHAMBERS EXCAVATOR.
(Both photos by Courtesy of Newton, Chambers & Co. Ltd.)

water which collects under the soil and is unable to percolate a hard subsoil, such as an impervious clay, callust or rock, is by no means unusual. Indeed, in thus spreading all over the site, it may well cause more inconvenience than a spring or underground river with a single channel. The first result of digging for foundations on such a site to a depth below the top of the impervious subsoil will be that the excavations will fill with water at a rate that any average pumping will be ineffective. The method of disposing of this subsoil water is, in theory, the same as that applied to the underground spring or river, though in practice it requires operations more widespread over the site. The principle is the same, *i.e.* to help the water on in the direction of its natural flow. A trench should first be opened up on the top side of the site, that is, on that side on which the water in its natural flow first reaches the site. This trench will then be found to fill with water with more or less rapidity, depending on the amount of water in the land, and in accordance with the contour of the subsoil. Trenches should then be dug down the site at right angles to the first trench, but as yet not communicating therewith. These should prove sufficient to drain away the water in the actual site until the operations next described can be completed. But should these cross trenches not suffice, pits or soak-away sumps should be sunk in their lengths, or a central sump may be sunk, having connections from each transverse trench. When this has been done, the transverse trenches may be connected to the trench first dug across the top of the site, and the result of this will be found to be that this topside trench is sufficiently drained to enable a 4-inch to 6-inch thick concrete wall to be formed against the face of the trench on its lower side. At the base of this wall an open half-round stoneware drain is set in a foundation of concrete at least 6 inches thick. This wall and open drain is continued across the whole topside of the site ; and from its ends either agricultural drainpipes or jointed drains may then be run down the other trenches into the central sump.

On a country site where ditches for drainage already exist, these should be cleaned out and all culverts looked to. The purpose of these ditches is different from that of those last described, in that it is surface water which they are required to accommodate as distinct from subsoil water. Where no ditches exist, these will require to be dug to falls in the direction of the natural flow of the water.

BOUNDARIES

Great care is necessary in defining the boundaries of property. On an open site, with no visible boundary walls or fences, the vendor of the land should have the boundaries pegged out by his surveyor. If there is any uncertainty about the exact position of boundaries, contact should be made with owners of adjoining properties and boundaries agreed with them.

Where there is a ditch in conjunction with a hedge or fence it may be assumed, in the absence of a deed plan exactly defining the boundary, that the bank was thrown up as the ditch was excavated and that the boundary runs along the side of the bank, as shown in Fig. 45, A.

With post and rail fences, the palings are assumed to be nailed on the outside of the property, and the property is therefore deemed to extend to the outside of the paling, and to include the fence. In other words, the fence where the boundary of the property is already known must be erected within that boundary, the outside of the palings coming directly above the boundary line.

Where streams divide property an imaginary line running down the centre of the stream is considered as the boundary of the property, and each owner is under equal obligations as to pollution, obstruction, diversion, or diminishing of flow.

Retaining Walls.—Sloping sites frequently call for retaining walls at their boundaries, and for terracing at various points within the boundaries.

A rule of thumb for the proportioning of retaining walls, given by Hurst, is that the thickness for about one-third is made equal to a third of the height. This thickness should be reduced towards the top in regular set-backs, and the face should have a batter of at least one in six towards the ground. Where the walls terminate level with the ground line, the thickness at the top should not be less than 18 inches, and the thickness just above each set-back should be from one-third to two-fifths of the height from the top of the wall to that point. Footings should be provided, and as these are, like all other brickwork, subject to frost, they should be taken down to at least 2 feet 6 inches below the ground.

At a height of a foot or so below the bottom, a retaining wall should be pierced every few feet with drain pipes to discharge any water which may collect in their rear.

Retaining walls are sometimes confused with breast walls. A retaining wall sustains made-up earth, whilst a breast wall is built to prevent a fall of earth already existing in its natural position, as in a cutting for a road or railway.

Reinforced concrete is now widely used for large retaining walls. Space and cost are less than with mass brick or mass concrete.

LAWS APPLYING TO TOWN SITES

On the town site, the contractor will meet with certain laws and regulations with which it will be necessary to comply if the conduct of the operations is to be smoothly carried on. As in some instances, party-wall notices, for example, it is required that a period of time shall elapse between the giving of the notice and the commencement of any operations, though such notices are generally served before tenders are obtained, the contractor should assure himself that this has been done from the

FIG. 32.—A RUSTON-BUCYRUS 10-RB $\frac{3}{8}$-CUBIC YARD DRAGSHOVEL EXCAVATING PIPE TRENCHES FOR A RURAL WATER SCHEME.

FIG. 33.—A RUSTON-BUCYRUS 19-RB $\frac{5}{8}$-CUBIC YARD DRAGSHOVEL TRENCH-DIGGING ON A HOUSING ESTATE.

FIG. 34.—A RUSTON-BUCYRUS 10-RB $\frac{3}{8}$-CUBIC YARD DRAGSHOVEL DIGGING TRENCHES ON A HOUSING ESTATE.

(All photos by courtesy of Ruston-Bucyrus Ltd.)

architect's office. When this precaution has not been taken, the contractor should arrange for the despatch of the notices as soon as a decision to tender has been arrived at.

NOTICES

The contractor will find any requirements of notices to be given before operations are commenced stated in the building by-laws applying. Should these not be clear, application should be made to the local authority concerned for definite information. In order that time may be saved, it is advisable to accompany such request for information with a block plan showing the site of the proposed new building and the adjoining properties, names of streets, etc.

In London, the London Building Act governs these matters, and there are many matters with regard to which applications may be required to be made to the London County Council, concerning not only the building site itself, but also the streets, sewers, electric supply; and for permission to occupy certain classes of buildings, licences have to be obtained.

Applications for licences must also be made to the local authority of any district for permission to erect hoardings, to shore up existing buildings, and for the erection of wooden buildings.

PARTY WALLS ON LINE OF JUNCTION OF ADJOINING LANDS

" *Definitions* (Part I of Act).—The expression ' party wall ' means :

(*a*) " A wall forming part of a building and used or constructed to be used for separation of adjoining buildings belonging to different owners or occupied or constructed or adapted to be occupied by different persons ; or

(*b*) " A wall forming part of a building and standing to a greater extent than the projection of the footings on lands of different owners.

" The expression ' building owner ' means such one of the owners of adjoining land as is desirous of building, or such one of the owners of buildings, storeys, or rooms separated from one another by a party wall or party structure, as does, or is desirous of doing, a work affecting that party wall or party structure.

" The expressions ' adjoining owner ' and ' adjoining occupier ' respectively mean any owner and any occupier of land, buildings, storeys, or rooms adjoining those of the building owner."

RIGHTS OF ADJOINING OWNERS

In the London Building Act the rights of Building and Adjoining Owners are set forth as follows in Part IX, section 113 :

" Where lands of different owners adjoin and are unbuilt on at the line of junction, and either owner is about to build on any part of the line of junction, the following provisions shall have effect :

(1) " If the building owner desires to build a party wall on the line of junction, he may serve notice thereof on the adjoining owner describing the intended wall;

(2) " If the adjoining owner consents to the building of a party wall, the wall shall be built half on the land of each of the two owners, or in such other position as may be agreed between the two owners;

(3) " The expense of the building of the party wall shall be from time to time defrayed by the two owners in due proportion, regard being had to the use made, and which may be made, of the wall by the two owners respectively;

(4) " If the adjoining owner do not consent to the building of a party wall, the building owner shall not build the wall otherwise than as an external wall placed wholly on his own land;

(5) " If the building owner do not desire to build a party wall on the line of junction, but desires to build an external wall placed wholly on his own land, he may serve notice thereof on the adjoining owner, describing the intended wall;

(6) " Where in either of the cases aforesaid the building owner proceeds to build an external wall on his own land, he shall have a right, at his own expense, at any time after the expiration of one month from the service of the notice, to place on the land of the adjoining owner, below the level of the lowest floor, the projecting footings of the external wall, with concrete or other solid substructure thereunder, making compensation to the adjoining owner or occupier for any damage occasioned thereby; the amount of such compensation, if any difference arises, to be determined in the manner in which differences between building owners and adjoining owners are hereinafter directed to be determined.

114. " The building owner shall have the following rights in relation to party structures (that is to say) :—

(1) " A right to make good underpin or repair any party structure which is defective or out of repair;

(2) " A right to pull down and rebuild any party structure which is so far defective or out of repair as to make it necessary or desirable to pull it down;

(3) " A right to pull down any timber or other partition which divides any buildings and does not conform to this Act, and to build instead a party wall conforming thereto;

(4) " In the case of buildings having rooms or storeys being the property of different owners intermixed, a right to pull down such of the said rooms or storeys, or any part thereof, as are not built in conformity with this Act, and to rebuild the same in conformity with this Act;

(5) " In the case of buildings connected by arches or communications over public ways, or over passages belonging to other persons, a right to pull down such of the said buildings, arches or communications, or such parts thereof, as are not built in conformity with this Act, and to rebuild the same in conformity with this Act;

(6) " A right to raise and underpin any party structure permitted by this Act to be raised or underpinned or any external wall built against such party structure, upon condition of making good all damage occasioned thereby to the adjoining premises, or to the internal finishings and decorations thereof, and of carrying up to the requisite height all flues and chimney stacks belonging to the adjoining owner, on or against such party structure or external wall;

(7) " A right to pull down any party structure which is of insufficient strength for any building intended to be built, and to rebuild the same of sufficient strength for the above purpose, upon condition of making good all damage occasioned thereby to the adjoining premises, or to the internal finishings and decorations thereof;

(8) " A right to cut into any party structure upon condition of making good all damage occasioned to the adjoining premises by such operations;

(9) " A right to cut away any footing or any chimney breasts, jambs or flues projecting or other projections, from any party wall or external walls, in order to erect an external wall against such party wall, or for any other purpose, upon condition of making good all damage occasioned to the adjoining premises by such operations;

(10) " A right to cut away or take down such parts of any wall or building of an adjoining owner as may be necessary in consequence of such wall or building overhanging the ground of the building owner, in order to erect an upright wall against the same, on condition of making good any damage sustained by the wall or building by reason of such cutting away or taking down;

(11) " A right to perform any other necessary works incident to the connection of a party structure with the premises adjoining thereto;

(12) " A right to raise a party fence wall, or to pull the same down and rebuild it as a party wall;

" Provided that all the rights conferred by paragraphs (1) to (11) inclusive of this section shall be subject to this qualification; that any building which was erected previously to the first day of January eighteen hundred and ninety-five shall be deemed to comply with the provisions of this Act if it complies with the provisions of the Acts of Parliament regulating buildings in London before that date.

115. (1) " Where a building owner proposes to exercise any of the foregoing rights with respect to party structures, the adjoining owner may by notice require the building owner to build on any such party structure such chimney, copings, jambs, or breasts, or flues, or such piers, or recesses, or any other like works as may fairly be required for the convenience of such adjoining owner and are specified in the notice; and it shall be the duty of the building owner to comply with such requisition in all cases where the execution of the required works will not be injurious to the building owner, or cause to him unnecessary inconvenience or unnecessary delay in the exercise of his right;

(2) " Any difference between a building owner and adjoining owner

in respect of the execution of any such works shall be determined in manner in which differences between building owners and adjoining owners are hereinafter directed to be determined.

116. (1) " A building owner shall not, except with the consent in writing of the adjoining owner and of the adjoining occupiers, or in cases where any wall or party structure is dangerous (in which cases the provisions of Part X of this Act shall apply), exercise any of his rights under this Act in respect of any party fence wall unless at least one month, or in respect of any party wall or party structure other than a party fence wall, unless at least two months before doing so he has served on the adjoining owner a party wall or party structure notice, stating the nature and particulars of the proposed work, and the time at which the work is proposed to be commenced;

(2) " When a building owner, in the exercise of any of his rights under this Part of the Act, lays open any part of the adjoining land or building, he shall, at his own expense, make and maintain for a proper time a proper hoarding and shoring, or temporary construction, for protection of the adjoining land or building and the security of the adjoining occupier;

(3) " A building owner shall not exercise any right by this Act given to him, in such manner or at such time as to cause unnecessary inconvenience to the adjoining owner or to the adjoining occupier;

(4) " A party wall or party structure notice shall not be available for the exercise of any right unless the work to which the notice relates is begun within six months after the service thereof and is prosecuted with due diligence;

(5) " Within one month after receipt of such notice the adjoining owner may serve on the building owner a notice requiring him to build on any such party structure any works to the construction of which he is hereinbefore declared to be entitled;

(6) " The last-mentioned notice shall specify the works required by the adjoining owner for his convenience and shall, if necessary, be accompanied by explanatory plans and drawings;

(7) " If either owner does not, within 14 days after the service on him of any notice under this section, express his consent thereto, he shall be considered as having dissented therefrom, and thereupon a difference shall be deemed to have arisen between the building owner and the adjoining owner.

117. (1) " In all cases not specially provided for by this Act where a difference arises between a building owner and adjoining owner in respect of any matter connected with any work to which any notice given under this Part of this Act relates, unless both parties concur in the appointment of one surveyor, they shall each appoint a surveyor, and the two surveyors so appointed shall select a third surveyor; and such one surveyor or three surveyors, or any two of them, shall settle any matter from time to time during the continuance of any work to which

the notice relates in dispute between such building and adjoining owner; with power, by his or their award, to determine the right to do, and the time and manner of doing, any work and generally any other matter arising out of or incidental to such difference; but any time so appointed for doing any work shall not unless otherwise agreed begin until after the expiration of the period by this Part of this Act prescribed for the notice in the particular case;

(2) " Any award given by such one surveyor, or by such three surveyors, or by any two of them, shall be conclusive, and shall not be questioned in any Court; with this exception, that either of the parties to the difference may appeal therefrom to the County Court within 14 days from the date of the delivery of the award; and the County Court may, subject as hereafter in this section mentioned, rescind the award or modify it in such manner as it thinks just;

(3) " If either party to the difference make default in appointing a surveyor for 10 days after notice has been served on him by the other party to make such appointment, the party giving the notice may make the appointment in the place of the party so making default;

(4) " The costs incurred in making or obtaining the award shall be paid by such party as the surveyor or surveyors determine;

(5) " If the appellant from any such award, on appearing before the County Court, declares his unwillingness to have the matter decided by that Court and proves to the satisfaction of the judge of that Court that, in the event of the matter being decided against him, he will be liable to pay a sum, exclusive of costs, exceeding 50 pounds, and gives security to be approved by the judge duly to prosecute his appeal, and to abide the event thereof, all proceedings in the County Court shall thereupon be stayed, and the appellant may bring an action in the High Court against the other party to the difference;

(6) " The plaintiff in such action shall deliver to the defendants an issue whereby the matters in difference between them may be tried; and the form of such issue, in case of dispute, or in case of non-appearance of the defendant, shall be settled by the High Court; and such action shall be prosecuted, and issue tried in the same manner, and subject to which, actions are prosecuted and issues tried in other cases within the jurisdiction of the High Court, or as near thereto as circumstances admit;

(7) " If the parties to any such action agree as to the facts, a special case may be stated for the opinion of the High Court; and any case so stated may be brought before the Court in like manner, and subject to the same incidents in, and subject to which, other special cases are brought before such Court, or as near thereto as circumstances admit; and any costs that may have been incurred in the County Court by the parties to such action as is mentioned in this section shall be deemed to be costs incurred in such action, and be payable accordingly;

(8) " Where both parties to the difference have concurred in the appointment of one surveyor for the settlement of such difference, then

if such surveyor refuse or for seven days neglect to act, or die, or become incapable to act, before he has made his award, the matters in dispute shall be determined in the same manner as if such single surveyor had not been appointed;

(9) " Where each party to the difference has appointed a surveyor for the settlement of the difference, and a third surveyor has been selected, then if such third surveyor refuse or for seven days neglect to act, or, before such difference is settled, die, or become incapable to act, the two surveyors shall forthwith select another third surveyor in his place; and every third surveyor so selected as last aforesaid shall have the same powers and authorities as were vested in his predecessor;

(10) " Where each party to the difference has appointed a surveyor for the settlement of the difference, then, if the two surveyors so appointed refuse, or for seven days after request of either party neglect, to select a third surveyor, or another third surveyor in the event of the refusal or neglect to act, death, or incapacity of the third surveyor for the time being, the Secretary of State may, on the application of either party, select some fit person to act as third surveyor; and every surveyor so selected shall have the same powers and authorities as if he had been selected by the two surveyors appointed by the parties;

(11) " Where each party to the difference has appointed a surveyor for the settlement of the difference, then, if before such difference is settled, either surveyor so appointed dies, or become incapable of acting, the party by whom such surveyor was appointed may appoint, in writing, some other surveyor to act in his place; and if for the space of seven days after notice served on him by the other party for that purpose, he fail to act, the other surveyor may proceed *ex parte*, and the decision of such other surveyor shall be as effectual as if he had been a single surveyor in whose appointment both parties had concurred; and every surveyor so to be substituted as aforesaid shall have the same powers and authorities as were vested in the former surveyor at the time of his death, or disability, as aforesaid;

(12) " Where each party to the difference has appointed a surveyor for the settlement of the difference, then, if either of the surveyors refuse, or for seven days neglect, to act, the other surveyor may proceed *ex parte*; and the decision of such other surveyor shall be as effectual as if he had been a single surveyor in whose appointment both parties had concurred.

118. " A building owner, his servants, agents and workmen, at all usual times of working, may enter and remain on any premises for the purposes of executing, and may execute, any work which he has become entitled or is required, in pursuance of this Act, to execute; removing any furniture, or doing any other necessary thing; and if the premises are closed, he and they may, accompanied by a constable or other officer of the peace, break open any fences or doors, in order to effect such entry:

" Provided that, before entering on any premises for the purpose of this section, the building owner shall, except in the case of emergency,

give 14 days' notice of his intention so to do to the owner and occupier, and in case of emergency shall give such notice as may be reasonably practicable.

119. " Where a building owner intends to erect, within 10 feet of a building belonging to an adjoining owner, a building or structure any part of which, within such 10 feet, extends to a lower level than the foundations of the building belonging to the adjoining owner ; he may, and if required by the adjoining owner shall (subject as hereinafter provided), underpin or otherwise strengthen the foundations of the said building, so far as may be necessary, and the following provisions shall have effect :—

(1) " At least two months' notice in writing shall be given by the building owner to the adjoining owner, stating his intention to build, and whether he proposes to underpin or otherwise strengthen the foundations of the said building ; and such notice shall be accompanied by a plan and sections showing the site of the proposed building, and the depth to which he proposes to excavate ;

(2) " If the adjoining owner, within 14 days after being served with such notice, give a counter-notice in writing that he disputes the necessity of or requires such underpinning or strengthening, a difference shall be deemed to have arisen between the building owner and the adjoining owner ;

(3) " The building owner shall be liable to compensate the adjoining owner and occupier for any inconvenience, loss or damage which may result to them by reason of the exercise of the powers conferred by this section ;

(4) " Nothing in this section contained shall relieve the building owner from any liability to which he would otherwise be subject, in case of injury caused by his building operations to the adjoining owner.

120. (1) " The following provisions shall apply with respect to expenses to be borne jointly by the building owner and adjoining owner :—

(*a*) " If any party structure is defective or out of repair ; the expense of making good underpinning, or repairing the same, shall be borne by the building owner and adjoining owner in due proportion, regard being had to the use that each owner makes or may make of the structure ;

(*b*) " If any party structure be pulled down and rebuilt by reason of its being so far defective, or out of repair, as to make it necessary or desirable to pull it down ; the expense of such pulling down and rebuilding shall be borne by the building owner and adjoining owner in due proportion, regard being had to the use that each owner may make of the structure ;

(*c*) " If any timber or other partition dividing a building be pulled down in exercise of the right by this Part of this Act vested in a building owner, and a party structure be built instead thereof ; the expense of building such party structure, and also of building any additional party structures that may be required by reason of the partition having been

pulled down, shall be borne by the building owner and adjoining owner in due proportion, regard being had to the use that each owner may make of the party structure, and to the thickness required for support of the respective buildings parted thereby ;

(*d*) " If any rooms or storeys, or any parts thereof, the property of different owners, and intermixed in any building, be pulled down in pursuance of the right by this Part of this Act vested in a building owner, and be rebuilt in conformity with this Act ; the expense of such pulling down and rebuilding shall be borne by the building owner and adjoining owner in due proportion, regard being had to the use that each owner may make of such rooms or storeys ;

(*e*) " If any arches or communications over public ways, or over passages belonging to other persons than the owners of the buildings connected by such arches or communications, or any parts thereof, be pulled down in pursuance of the right by this Part of this Act vested in a building owner, and be rebuilt in conformity with this Act ; the expense of such pulling down and rebuilding shall be borne by the building owner and adjoining owner in due proportion, regard being had to the use that each owner may make of such arches or communications.

(2) " The following provisions shall apply with respect to expenses to be borne by the building owner :

(*a*) " If any party structure, or any external wall built against another external wall, be raised or underpinned in pursuance of the power by this Part of this Act vested in a building owner ; the expense of raising or underpinning the same, and of making good all damage occasioned thereby and of carrying up to the requisite height all such flues or chimney stacks belonging to the adjoining owner on or against any such party structure or external wall, as are by this Part of this Act required to be made good and carried up, shall be borne by the building owner ;

(*b*) " If any party structure which is of proper materials and sound, or not so far defective or out of repair as to make it necessary or desirable to pull it down, be pulled down and rebuilt by the building owner ; the expense of pulling down and rebuilding the same, and of making good any damage by this Part of this Act required to be made good and a fair allowance in respect of the disturbance and inconvenience caused to the adjoining owner, shall be borne by the building owner ;

(*c*) " If any party structure be cut into by the building owner ; the expense of cutting into the same, and of making good any damage by this Part of this Act required to be made good, shall be borne by the building owner ;

(*d*) " If any footing, chimney breast, jambs, or floor be cut away in pursuance of the powers by this Part of this Act vested in a building owner ; the expense of such cutting away, and of making good any damage by this Part of this Act required to be made good, shall be borne by the building owner ;

(*e*) " If any party fence wall be raised for a building ; the expense of raising such wall shall be borne by the building owner ;

(*f*) " If any party fence wall be pulled down and built as a party wall ; the expense of pulling down such a party fence wall and building the same as a party wall shall be borne by the building owner.

(3) " If at any time the adjoining owner makes use of any party structure or external wall (or any part thereof) raised or underpinned as aforesaid, or of any party fence wall pulled down and built as a party wall (or any part thereof), beyond the use thereof made by him before the alteration ; there shall be borne by the adjoining owner from time to time a due proportion of the expenses (regard being had to the use that the adjoining owner may make thereof) :

(i) " Of raising or underpinning such party structure or external wall, and of making good all such damage occasioned thereby to the adjoining owner, and of carrying up to the requisite height all such flues and chimney stacks belonging to the adjoining owner, on or against any such party structure or external wall, as are by this Part of this Act required to be made good and carried up.

(ii) " Of pulling down and building such party fence wall as a party wall.

121. (1) " An adjoining owner may, if he thinks fit, by notice in writing, require the building owner (before beginning any work which he may be authorised by this Part of this Act to execute) to give such security as may be agreed upon, or in case of difference may be settled by the Judge of the County Court, for the payment of all such expenses, costs, and compensation in respect of the work as may be payable by the building owner ;

(2) "The building owner may, if he thinks fit at any time after service on him of a party wall or party structure requisition by the adjoining owner, and before beginning a work to which the requisition relates, but not afterwards, serve a counter requisition on the adjoining owner requiring him to give such security for payment of the expenses, costs, and compensation for which he is or will be liable, as may be agreed upon, or in case of difference may be settled as aforesaid ;

(3) " If the adjoining owner do not, within one month after service of such a counter notice as aforesaid, give security accordingly, he shall, at the end of that month, be deemed to have ceased to be entitled to compliance with his notice served under subsection (1) of this section, and the building owner may proceed as if no party wall or party structure requisition had been served on him by the adjoining owner.

122. " Within one month after the completion of any work which a building owner is by this Part of this Act authorised or required to execute, and the expense of which is in whole or in part to be borne by an adjoining owner the building owner shall deliver to the adjoining owner an account in writing of the particulars and expense of the work, specifying any deduction to which such adjoining owner or other person

may be entitled in respect of old materials, or in other respects; and every such work shall be estimated and valued at fair average rates and prices, according to the nature of the work and the locality and the market price of materials and labour at the time.

123. "At any time within one month after the delivery of the said account, the adjoining owner, if dissatisfied therewith, may declare his dissatisfaction to the building owner by notice in writing served by himself or his agent, and specifying his objection thereto, and thereupon a difference shall be deemed to have arisen between the parties, and shall be determined in manner hereinbefore in this Part of this Act provided for the settlement of differences between building and adjoining owners.

124. "If, within the said period of one month, the adjoining owner do not declare in the said manner his dissatisfaction with the account, he shall be deemed to have accepted the same, and shall pay the same on demand to the party delivering the account, and if he fail to do so the amount so due may be recovered as a debt.

125. "Where the adjoining owner is liable to contribute to the expenses of building any party structure, then, until such contribution is paid, the building owner at whose expense the same was built shall stand possessed of the sole property in the structure.

126. "The adjoining owner shall be liable for all expenses incurred on his requisition by the building owner, and in default payment of the same may be recovered from him as a debt.

127. "Nothing in this Act shall authorise any interference with an easement of light or other easements in or relating to a party wall, or prejudicially affect any right of any person to preserve or restore any light or other thing in or connected with a party wall, in case of the party wall being pulled down or rebuilt."

MECHANICAL EXCAVATION

The following are the chief applications of excavators to building construction and incidental works: (1) excavation for foundations and basements; (2) clearing and levelling of sites; (3) digging of trenches for water, sewage, gas, etc., mains; (4) construction of roads; (5) lifting and handling of materials, pipes, etc.

For all but the smallest jobs site preparation is now carried out with the aid of excavating machinery.

The General Purpose or Universal Excavator consists of a power unit with caterpillar tracks for supporting the moving equipment. The interchangeable equipment includes shovel, dragline, back trencher, grabber and skimmer, crane and pile driver. In most cases pile driving equipment can be added.

The Bulldozer is used for pushing loose surface soil and other material for distances up to 200 feet. It consists of a tractor fitted at the front with a large steel plate with a cutting blade on the lower edge, the length being from 6 feet to 13 feet.

The Scraper consists of a wagon equipment drawn by a tractor, which digs, loads and carries the surface soil up to distances of 2,500 feet. Capacities are from 4 to 12 cubic yards.

The Ripper is a scarifier drawn by a tractor. It is used to break up heavy surfaces preparatory to using the bulldozer or scraper.

The Trencher or Ditcher is a machine with a series of sharp-edged buckets mounted on an endless chain. In motion the buckets dig into the earth to a desired depth up to about 8 feet by 2 feet wide, with a top cutting speed of 8 feet per minute.

The Tamping Roller studded with steel "sheeps' feet"—projections which have the same tamping effect as a flock of sheep. The soil is spread in 6-inch layers and the tamping roller compacts each layer. This roller is used where levels have to be made up for roads, drives and under concrete floors which have to bear loads.

Sizes.—General purpose excavators have capacities of from 5 cubic feet to $1\frac{1}{4}$ cubic yards. For work of moderate extent the $\frac{3}{8}$, $\frac{1}{2}$ and $\frac{5}{8}$ cubic yard capacities are widely used. The size and type of machine must be suited to the job, with power and capacity to spare, if breakdowns are to be avoided.

For the smaller general purpose machines, petrol or petrol-paraffin engines are usual, but for machines of $\frac{3}{8}$ cubic yard and upwards, diesel engines are used.

Caterpillar tractors for earth-moving equipment are usually powered with diesel engines, ranging from 25 to 120 horse power. The caterpillar treads are designed to give a ground load of about 6 pounds per square inch. There are usually six gears, speeds ranging from about $1\frac{3}{4}$ to $4\frac{1}{2}$ miles per hour.

CHAPTER 3

SURVEYING AND LEVELLING

Preliminary.—In forms of contract for works of any importance, there may be found a note that the contractor is to be responsible for the checking of all levels and dimensions shown on the plans. For this and other purposes it is necessary that a contractor should have some knowledge of surveying and levelling.

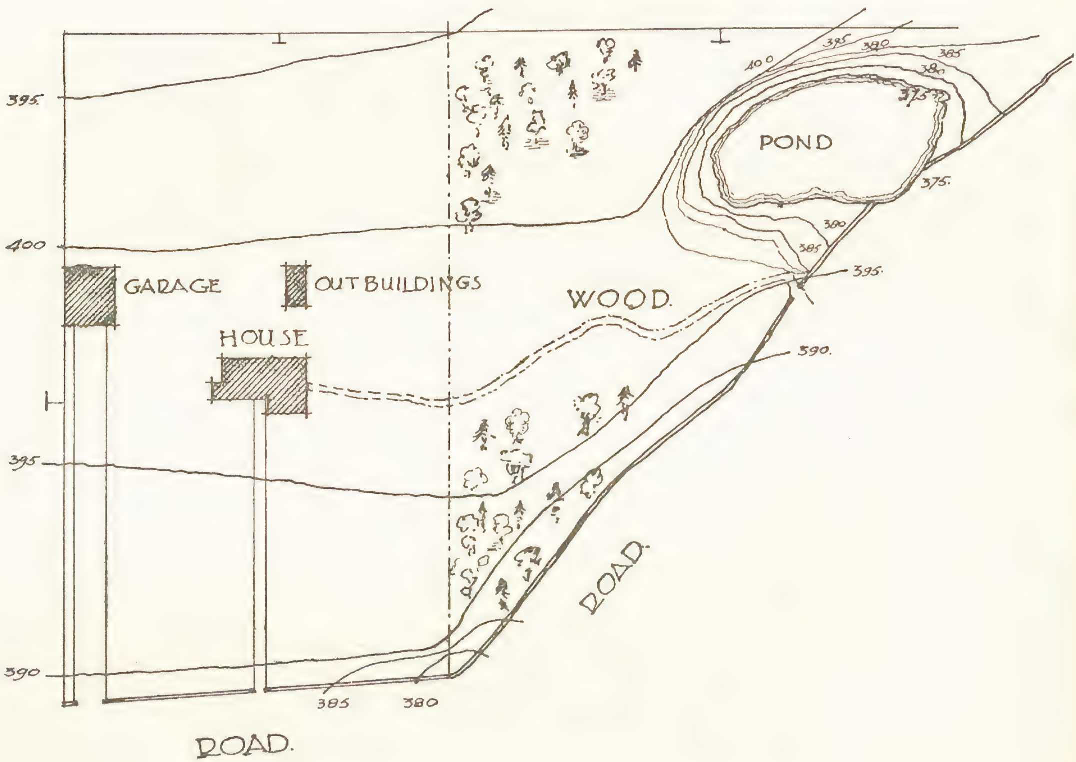


Fig. 35.—Site plan.

Before a building can be designed to suit a particular site, the dimensions of that site must be taken and a plan drawn to scale. This plan, besides giving the area of the site, must also convey the levels or the contours as the variations in level are called.

Instruments.—In land surveying the measurements are taken by either a chain or a tape measure, and if the latter is used it is preferable when made of steel which prevents stretching.

The Chain measures 66 feet in length, and is composed of 100 links—so that each link measures 7·92 inches. The engineer's chain is 100 feet in length, having 100 divisions.

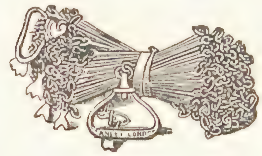


Fig. 36.—The surveyor's chain.

At the end of the chain the links are fitted with brass handles, and at the end of every tenth link there is a brass "tally" having prongs denoting the multiple of 10 links which it represents. That is to say, the first has one prong, and that at the twentieth link two prongs, and as this method of indication is started from each end, the eightieth link will also have two prongs.

For pegging a line, there are also supplied with the chain ten steel pins having their top ends bent into a ring.

The Tape is generally of the same length as the chain, and the links marked on the reverse side to that which shows the feet and inches. The tape must be used in conjunction with the chain in taking "offset dimensions," as is described later.

Rods from 5 feet to 12 feet in length, shod with metal points and divided into feet with colours, are used for making station points as explained later.

Chaining.—In measuring a straight line with a chain the line should first be sighted in the desired direction, the rods being used for this purpose. If the distance is not a great one, three rods will be sufficient, one being fixed at the beginning of the line and the other at the end, the position of the intermediate one being found by sighting with the eye along the line between the two fixed rods. The exact position of this intermediate rod is found by an assistant "offering" it up and moving it either forwards or backwards at the direction of the surveyor sighting from the end.

Offsets.—Having obtained the straight line along the length of the portion of land to be surveyed, the boundaries may be roughly plotted by taking a few offsets from this straight line.

These offsets are lines at right angles to the main line, and are obtained by means of the tape measure. This is held at the ring end over a point on the boundary, whilst a reading is taken of the least distance from that point to the main line. The least distance is obtained by holding the tape over the main line and walking forwards and back again until the lowest figure on the tape comes directly over the main line, *i.e.* the chain.

The distance of this right-angle line from one end of the tape should then be measured and noted ; and pegs should be driven in at both ends of the right-angle line.

Check Dimensions.—A check dimension or tie should then be taken from the starting end of the chain or main line to the point on the boundary to which the right-angle line was taken. In plotting the survey to scale, there will thus be two dimensions from the main line to the point

on the boundary which must, if they have been correctly measured coincide. A check on the exactness of the survey is thus obtained.

Triangulation.—This method of taking check dimensions and dividing the land up into triangles is the basis of the principle underlying all surveying. Any point at any distance or in any direction from the base or main line may be obtained by taking two points on the main line and measuring the distance of the one point from one end of the main line and the distance of the other point from the other end. The distance of the point which it is desired to locate on the plan is then measured from these two points on the main line.

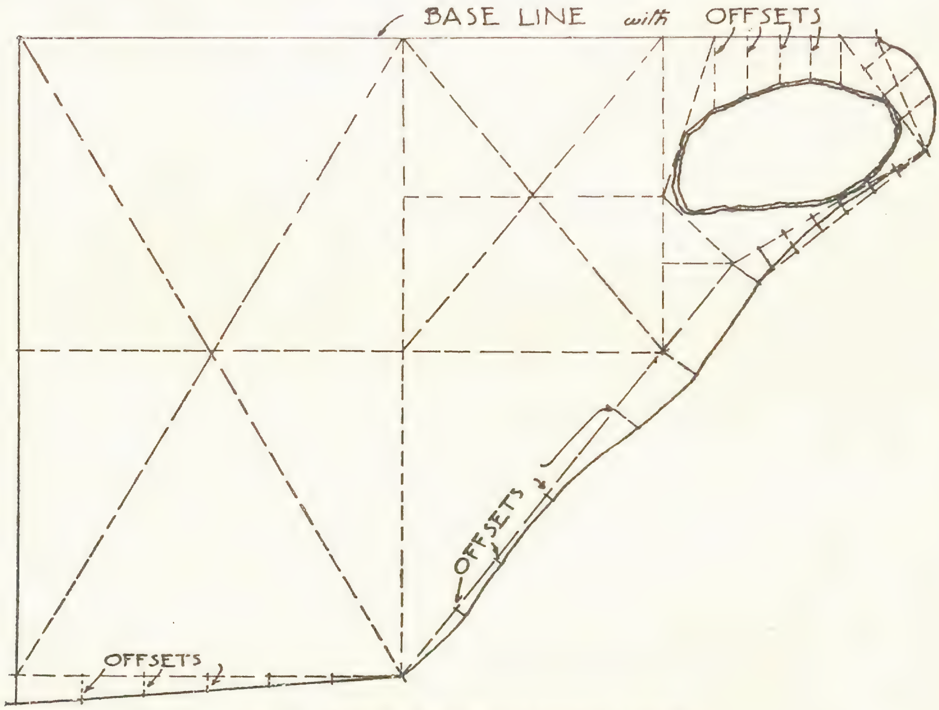


Fig. 37.—Survey of site plan showing offsets.

The actual drawing operation performed in plotting this on the plan is as follows: after the distances on the main line have been plotted on the plan, one leg of the compass is placed on one point and the other leg opened out the required distance to describe an arc of a circle having a radius of the length of the distance from that point to the point whose position it is desired to find. An arc is then struck somewhere in the neighbourhood of the position of the point desired. A similar operation is then performed with the compasses, having the other point on the main line as centre and the other measurement from that point to the desired point as radius, and another arc is struck. The point of intersection of these two arcs gives the exact position of the point desired.

It will be obvious that, whereas it is possible to obtain a right-angled

triangle, this will afford an additional check. Or if this is not possible, an equilateral triangle will save time and trouble in plotting.

Plotting.—The term plotting in surveying merely means the drawing to scale of the dimensions taken. For the purposes of accuracy in surveying and ease in reading the survey when plotting, a *Field Book* should be used.

The Scales used in plotting surveys of land are necessarily different from those used in preparing working drawings of buildings. Whereas the scales used in making working drawings are 1 inch, $\frac{1}{2}$ inch, $\frac{1}{4}$ inch, and $\frac{1}{8}$ inch to a foot, the scales to which surveys of land are drawn are 44 feet and 88 feet to an inch, 1/2,500 and 6 inches to the mile.

A typical *Field Book* is one which is so formed as to open lengthwise, having its pages ruled in the long dimension, with two parallel lines down the centre of each page. In the space between these lines the measurements of the distance of marked points on the chain line are noted. In the spaces on the right and left of these chain readings the measurements of offsets right and left are noted opposite the chain readings from which they are taken.

The chain readings, however, should be noted in the field book in the opposite manner from the usual ; that is, they should be started at the bottom. This simplifies the work, as the readings then correspond with the position and the direction of the person taking the survey. From this it will be obvious that the book must be started from the back instead of the more customary method of starting from the front.

A rough sketch of the boundary on either hand may be made in the margins of the field book as the readings proceed, or the plan of the site may be roughly drawn on a sheet of drawing-paper and lettered to correspond with the readings in the field book. Some surveyors fasten this sheet of paper to a small drawing-board that is fitted with straps, which pass over the shoulders to hold the board in a position to leave both hands free. The plotting is then proceeded with to scale as the work of measuring is carried out by his assistants. This latter method has the advantage that it permits of the accuracy of the survey being assured whilst there is still opportunity of retaking any measurements before the site is left.

Signs.—There are certain signs recognised by the Ordnance Department which the surveyor uses in denoting certain accepted features commonly used in ordinary surveying. These sketched in the margins of the field book will save considerable time and note-making, will be readily recognisable, and will be found below.

Making the Survey.—There are two ways of making a survey. It may be plotted to scale as the measurements are taken, which saves considerable time, as any inaccuracies will be disclosed whilst the surveyor is still on the site, or it can be noted in the field book.

The first method is more suitable for small sites than for large ones,

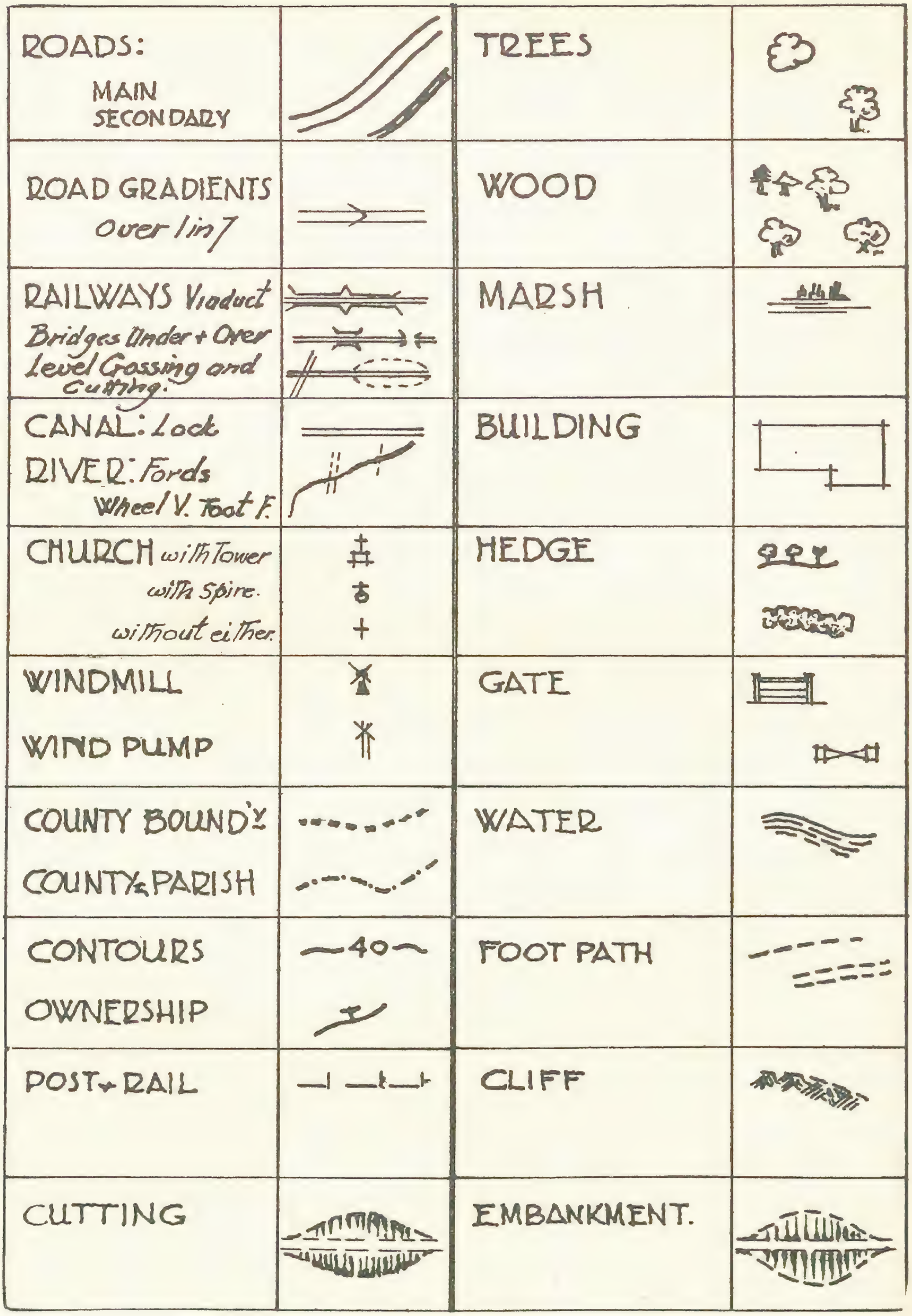


Fig. 38.—Ordnance signs.

and for both the site should be first plotted from the ordnance map to a scale giving a convenient-sized drawing. This drawing is pinned to a portable drawing-board, and the site is then walked over with the drawing in hand.

In the first method the dimensions from the drawing are checked, and if required altered to the actual measurement. The site drawing will have previously been divided up into as many convenient triangles as possible, which will expedite the work on the site. On these lines there should be marked in circles figures denoting the order in which they are to be measured. These figures are to be noted in the field book.

The first point to be settled on the site is to establish a *base line* from which all measurements taken may be referred back. Where possible this base line should extend across the site from its most distant points, and this line will be marked (1). On this line are marked points called "Station Points," from which offsets to the boundaries are to be taken. The line, as it will be required to be maintained during the whole of the survey, should be pegged out with wooden pegs, the station points being lettered on the pegs and on the plan to correspond, the same reference letters being noted in the field book. This line is then measured and noted, and the offsets taken from it are also measured (see Fig. 37).

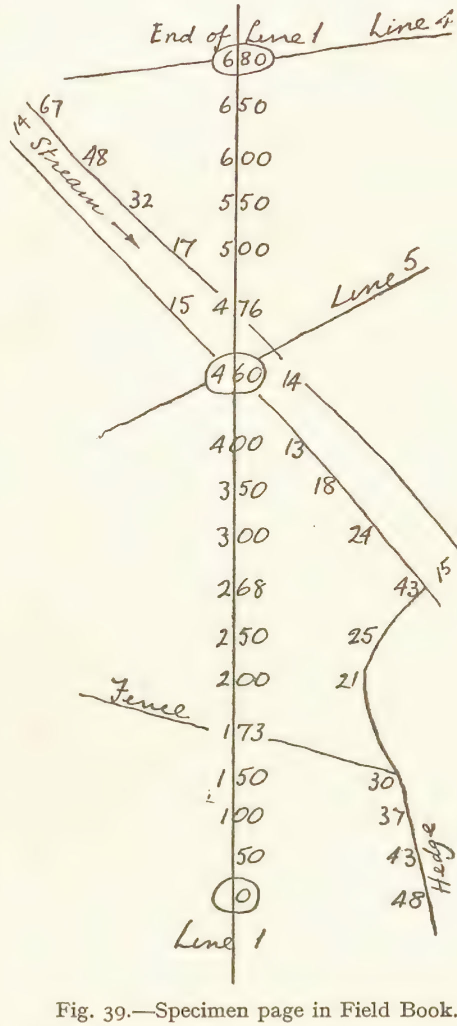


Fig. 39.—Specimen page in Field Book.

Figures on centre line are distances in feet. Offsets are taken at right angles to this line and offset distances entered to right and left against the features to which they refer.

The Field Book.—In this method of recording the survey the base and triangulation lines, as shown in Fig. 37, should be numbered Line 1, Line 2, and so on. Measured distances along these lines can then be booked as in Fig. 39. Offsets at right angles to the lines to fix the positions of hedges, fences, watercourses and other features are also measured and booked as shown.

Offsets at Right Angles.—In order to lay out an offset at right angles to the base line, the simple proposition, that the square on the hypotenuse

of a right-angled triangle is equal to the squares on the other two sides, is made use of. A distance of 60 feet, for example, is measured along the base line from the point at which it is desired to take the offset. The end of the tape is then held at this point, and a distance of 80 feet is measured in the direction of the required offset ; another tape is then held at the point 60 feet from the offset station, and at the other end the 100-foot mark is circled round until it coincides with the 80-foot mark on the tape held along the offset line. When these two—100-foot and 80-foot—marks coincide, the line drawn from the offset point to the point of coincidence will give the direction through which the offset at right angles to the base line must be drawn.

In actual practice, considerable time is to be saved by having two assistants to hold the two tapes, the one at the 80-foot mark and the other at the 100-foot mark. These assistants then walk backwards and forwards with the other ends of these tapes pegged to the base line, describing lessening arcs of circles until the two (100-foot and 80-foot) marks coincide.

For greater exactitude a similar triangle may be measured on the other side of the base line from the station point—when the coincidence of the 80-foot and 100-foot marks should come exactly over the coincidence already found.

This method of setting out a right angle is often called the 3 : 4 : 5 method, these figures being the ratios of the two sides and hypotenuse of the triangle. Thus, any multiples of 3 : 4 : 5 may be used in setting out. For example, 15 feet : 20 feet : 25 feet. Or 60 feet : 80 feet : 100 feet, as above.

The Cross Staff and Optical Square are instruments constructed to give right-angled offsets by sighting, and afford accurate means of saving time in obtaining the required results.

The Cross Staff is a metal box fitted on a socket on a short rod. In the box are cut four slits in two parts, one narrow and the other wider. In the wider slit there is a hair line or wire fixed down the centre of the slit. The eye is placed at one of the narrow slits and the instrument turned until the cross wire in the wider slit opposite coincides with it and a pole on the base line. The right-angle line is then found by placing the eye to the next narrow slit, and fixing a rod to coincide with the hair line in the opposite wider slit.

Fig. 40.—The Optical Square and cross staff.

In the Optical Square two mirrors are fixed at such an angle that two points at right angles can be made to coincide when seen through the instrument containing the mirror. The whole surface of one mirror is formed with a reflecting surface, whilst only the lower half of the second is so prepared, the upper half being clear glass.

In operation a point is sighted along the base line through the clear-glass upper half of the second mirror, and a staff is then held at a point approximately at right angles to this, and moved slowly backwards and forwards until its reflection in the lower, reflecting half of the mirror forms a straight line with the pole seen through the clear glass. Lines then running from the station point to these two poles are at right angles.

The same result can be obtained by revolving the level through 90° and fixing poles exactly coinciding with the hair line in the level telescope. But unless levels are to be taken also, it is more convenient to take the smaller instrument.

Fig. 41.—Ordnance map showing contour line.

LEVELLING OPERATION

The operation of levelling is carried out in conjunction with surveying, as in order to build on a site it is necessary to know the slopes of the ground.

These slopes are shown on a plan either by section lines through points, the level of which it is required to know, or all over the plan by lines, in a different-coloured ink, running through all points of the same level. The lines are termed *Contour Lines.* To anyone experienced in reading plans, the section or slope of any particular part of a site is readily discernible from the contour lines.

Suppose that the contour lines are drawn through points of the same level at every 10 feet fall or rise. If, therefore, the contour lines are very close together at one part and far apart at another, as each line denotes a difference of level of 10 feet, it is clear that the slope must be much more rapid where the lines are close together than where they are farther apart.

The Dumpy Level.—These slopes or differences of level are obtained by the use of an instrument known as the *Dumpy Level.*

The principle underlying the dumpy level is that of the spirit level, with which every carpenter is well acquainted, combined with a telescope for reading heights on a staff held at points in the distance, the level of which it is desired to ascertain.

As will be known, the component parts of a spirit level are a glass tube with a slightly curved outline having an air bubble in a quantity of alcohol. The air is lighter than the spirit, with the result that as the level is moved, the bubble will rise to the top of the spirit. Two points are marked in the centre of the glass tube and when the level is so held that the bubble comes between these two points, the instrument then forms part of a level line. The glass tube is set in a length of wood, brass bound, and of a convenient length. For ordinary levelling operations on a building, such as levelling brick courses, bottoms of drain trenches, etc., etc., this instrument, together with a straightedge, is all that is required. But for determining the levels of points of land some considerable distance away, the telescope and the staff referred to above are necessary.

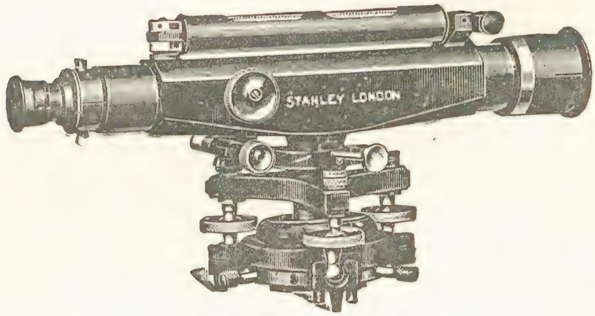


Fig. 42.—The dumpy level.

There is, however, no more difficulty attaching to the use of the one than to that of the other; except, perhaps, in the reading of the figures on the staff, as these show through the telescope upside down. This is a matter which custom and practice soon adjust.

The Staff when closed is generally about 5 feet in length, having two extensions which stick one within the other in the manner of a telescope. When pulled out for use these extensions fit into a safety catch, which holds them extended as required.

On the inner face of the staff will be found figures which may at first seem to be arranged in a manner unnecessarily vague, but examination and practice will prove that when seen through the dumpy level they are so arranged that they may be the more easily discernible. Before sighting a reading through the level it will be advisable to study the figures close at hand. On the left hand of the scale of lines will be found large figures painted in red. These are the feet dimensions. On the right hand of the scale are figures in black, *which are not inches* but tenths of a foot. This is a point which sometimes causes trouble to the beginner. But as all level dimensions in surveying are worked out in tenths of a foot, if the point is grasped at the outset, it is no more difficult than if the subdimensions were to be in inches.

In both cases—with the feet and with the tenths of a foot—*the top*

of the numeral corresponds with the line on the scale to which it has reference. When seen through the telescope of the level, this will be the top of the numeral reversed. It will be noticed that the figures on the right hand are exactly one-tenth of a foot in height, so that the bottom of the figure 7, for instance, comes opposite the line representing 6 on the scale. This is a matter which will be found helpful to bear in mind when readings are taken with the staff so close to the level that the figures above and below cannot be seen.

In such circumstances it will also be helpful if the staff be raised up and then lowered again until the next foot figure comes into view of the telescope.

Each tenth of a foot is further divided into 5, and each dividing line is of the same width as the space between, so that each space and each line represents a tenth of a tenth of a foot $= \frac{1}{100}$ foot. This is written as follows, if say the third line above the top of the 3 is indicated $= 0{\cdot}33$.

The readings are made by noting the figures that are seen opposite the horizontal hair line which, as is described later, is formed in the diaphragm of the level telescope.

Using the Level.—Having thoroughly acquainted oneself with the staff—and a certain amount of practice in reading this close at hand with the naked eye and the staff upside down is recommended—the next step is a preliminary study of the level followed by some preliminary practice in sighting objects readily discernible, leaving reading the staff through the level until one becomes accustomed to sighting with one eye.

The Level Telescope most used is that known as the dumpy level, and consists of a telescope fixed to a bar underneath it, and having a spirit level in a circular tube fixed above it. Some levels have the spirit level fixed to the side of the telescope, which renders reading an easier matter during the operation of setting up the level in such a manner that the spirit level gives no indication of any alteration when turned in any direction.

This operation is one that sometimes occasions difficulty to the beginner; however, as in all these matters, practice dissolves the apparent difficulty.

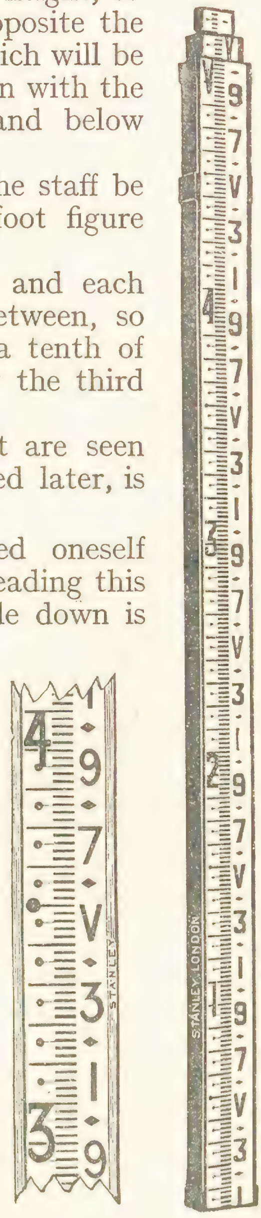


Fig. 43.—The staff.

The first operation is to set the tripod stand of the level firmly on the ground with the legs forming an angle of about 60° with the ground. It is essential that the legs of the tripod should be settled firmly into the ground. The feet of the legs will be found to be shod with metal for this purpose; and the position once established, the operator

must accustom himself to moving round the tripod without kicking the legs.

Under the bar of the telescope will be found either three or four screws according to the type of the level. With the former the level is set in a line parallel to two of the screws, and with the latter it is set in a line across the centre of two opposite screws.

Then revolve the screws, when the bubble in the spirit level will be found to travel in one direction or the other, along the spirit level. Continue adjusting the screws until the bubble is in the centre of the spirit tube. It will at once be discovered that the screws turn in opposite directions, and it will be found that adjustments are more readily effected by turning two screws at the same time. The telescope is then turned at right angles to its first position, then the other screws or screw adjusted until the spirit level gives a level reading. It will then be found that when the telescope is revolved back to its original position, the first level reading will have been altered, and a second adjustment of the screws will be required. Proceed in this way until, by a process of elimination, readings of the spirit level in both positions and in all intermediate positions indicate no alterations in the level of the telescope. Before taking the next step, see that all screws are tight up against the plate to which the telescope is fixed.

The next operation is to look through the telescope, adjusting the eyepiece so that the hair lines are in fours, *i.e.* clearly defined in outline. Then sight the staff along the top of the telescope, afterwards looking through the telescope and focusing the figures seen on the staff—the line or space between the line, as has been explained, through which the horizontal hair line cuts, gives the reading for the level of the point at which the staff is held.

It must, however, be recognised that this " level " bears no relation to anything other than that it is the point at which the level line drawn from the observer's eye cuts the staff held at a certain position. In order to give this reading some relative value, the staff must be held on a datum level ; the height or depth above or below sea-level is known from the Ordnance Survey. All other readings taken afterwards from the same station point bear a relation to this datum level.

To find the difference of level between two points, readings must be taken in the manner described on the staff held at the two points, when the levels noted must be subtracted one from the other. The result gives the difference of level, *i.e.* the slope of the ground between those two points. However, it generally happens, wherever there is any decided slope to the site, that the readings cannot be taken on to the staff held at all the points, the level of which it is desired to know, by the level stationed at a point from which the datum can be seen. The level will be found at, say, the third position of the staff to sight either below the foot or over the head of the staff, according to whether the ground rises or falls. In such circumstances a position for the level must be chosen from which

as many station points as possible of the staff may be seen. The first reading taken by the level on to the datum is termed *the back sight.*

When all the readings have been taken which can be seen with the level in that position, the level must be moved to a second position, from which the staff can be seen still held in the position in which the last reading was taken. This last reading from the first position is called *a foresight,* and the next reading taken from the new station point of the level on to the staff still held in the same position is called the *second back sight.*

Books specially prepared for levelling will be found to comprise ruled spaces named, *Back Sight; Intermediate; Foresight; Rise; Fall; Reduced Level; Distance;* and *Remarks.* The meanings of back sight and foresight have already been explained; and an intermediate reading is any level other than a back sight and foresight. The "rise" and "fall" are self-explanatory terms, but the "reduced level" requires some explanation, though this is quite simple. It merely means the level with regard to the original datum, which is worked out from the rise-and-fall columns. If the first figure in the reduced levels be subtracted from the last figure, this will give the difference between these two levels with reference to the datum. This may be checked by adding up the back sight and the foresight columns, and deducting the lesser from the greater, and the result should equal the difference found in the reduced-level column. The same result can be obtained by adding up the rise and fall columns, and subtracting one from the other. If these results all come to the same, it is a proof of the accuracy of the levelling.

Example of Levelling.—Fig. 44 illustrates the dumpy-level and staff positions taken up to obtain the levels of the land. The black arrow on

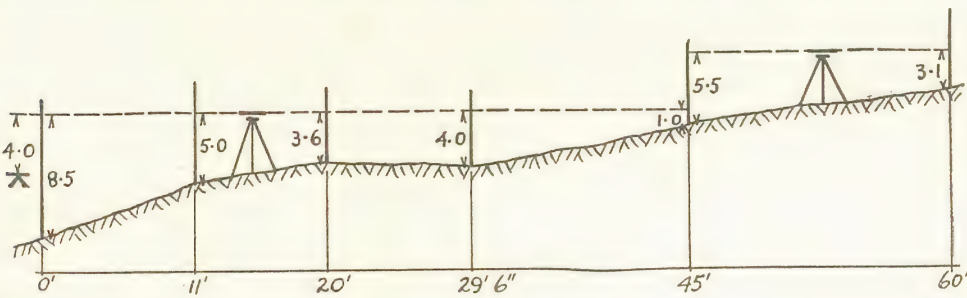


Fig. 44.—Example of levelling.

the left is an Ordnance Survey bench mark on a wall. It is 110 feet above mean sea-level (as indicated on the Ordnance Map), and mean sea-level is taken as the datum for the levelling.

The staff readings are entered on the rise-and-fall method, (page 58). The staff readings are also shown in Fig. 44, and by comparing the illustration with the entries and reduced levels below, it will be seen how the method works.

The bench mark on the wall is taken as the first back sight, so that

there is a fall between the bench mark and the first staff position of 4·5 feet. This is subtracted from the bench-mark datum to give the reduced level of the first staff position, thus 110 − 4·5 = 105·5.

The first intermediate staff reading of 5 feet gives the rise above the previous staff position of 8·5 − 5·0 = 3·5. Add this to the previous reduced level, thus 105·5 + 3·5 = 109 feet. And so on.

LEVELS ALONG A STRAIGHT LINE FROM A TO B (Fig. 44)

Back Sight.	Inter. Sight.	Foresight.	Rise.	Fall.	Reduced Level.	Distance from A.	Remarks.
4·0	—	—	—	—	110·0	—	Bench mark on wall 110 feet above sea-level.
—	8·5	—	—	4·5	105·5	—	
—	5·0	—	3·5	—	109·0	11′ 0″	
—	3·6	—	1·4	—	110·4	20′ 0″	
—	4·0	—	—	0·4	110·0	29′ 6″	
5·5	—	1·0	3·0	—	113·0	45′ 0″	
—	—	3·1	2·4	—	115·4	60′ 0″	
9·5	—	4·1	10·3	4·9	115·4	—	Check.
4·1	—	—	4·9	—	110·0	—	
—			—		——		
5·4			5·4		5·4		

Causes of Error in Levelling.—Errors may arise resulting in the figures not working out in the manner explained above, and whilst the surveyor may feel justified in believing his readings to have been taken with accuracy, the results prove that errors must have crept in somehow. The following are some of the most usual causes of error :

(1) The staff is not fully extended. This is a particularly irritating form of carelessness, and one which may not be discovered until the whole of the readings have been taken, unless the reduced levels are worked out as the levelling proceeds. When opening out the staff preparatory to starting, care should be used in seeing that each of the upper portions is pulled out to its fullest extent. When this is done properly, the ball safety catch will make a click as it is sprung back into the circle prepared for its reception.

(2) The level itself may not have been truly levelled before the readings were commenced. How this should be done has been explained. The level itself may be out of adjustment and in a condition in which it cannot be made to give level readings when revolved at right angles. As this requires adjustment of the capstan screws, it is advisable to consult the makers.

(3) The staff may not have been held perpendicularly. It is as well to get the assistant to lean the staff slowly sideways in each direction and backwards and forwards, and to take the lowest reading in each case.

(4) Back sights should, where possible, be taken from an equal distance as foresights. This may be found rather irritating when levelling up a steep slope. As the bottom of the staff soon, owing to the rise, cannot

be seen through the telescope, which, at most, is only 5 feet above the ground at the point from where the reading is to be taken, whereas the staff, being about 15 feet long, can be seen for much farther distances looking downwards, it is advisable, when levelling steep gradients to make the station points of the level at the side of the line along which the staff is placed.

(5) Forgetfulness to take, or inaccuracies in taking and noting, the distances of the staff station points leads to error. Never move from a station point until the column "Distances" is filled in. Nothing is more annoying when it comes to plotting the levels than to find one has a level reading, but no indication as to where the point is of which the reading is the level.

Levelling and Measuring round and over Obstacles is performed by the application of triangulation. For instance, if a building interrupts a straight line along which it is desired to measure (Fig. 46), set out a distance along the line A B from the interposing building 2 to 1, and then from 1 and 2 set out lines at right angles in the manner already explained. The length of these lines at right angles from 1 and 2 should be equal and of sufficient length to clear the obstruction. Join 2 and 4, and measure the distance between them. If the lines 1 to 3 and 2 to 4 have been set out correctly at right angles, the distance 3 to 4 should equal the distance 1 to 2. This can be checked by measuring the distances 2 to 3 and 1 to 4, which should be equal to one another.

Then produce the line 4 to 3 until the obstructing building is passed, and erect a line at right angles to the line 4 to 3 produced, calling the point from which the right-angled line is run 7. From 7 extend the line 4, 3, 7 to 8, making the distance 7 to 8 equal to the distance 3 to 4. From the point 8 project a line at right angles to the line 3 to 8. Measure down the lines projected at right angles from 7 and 8, distances equal to 1 to 3, calling the points at the end of these distances 5 to 6. Join 5 and 6, and measure the distance between. This should equal the distance 7 to 8. And if that is found to be so, then 5 and 6 is the continuation of the line A B desired.

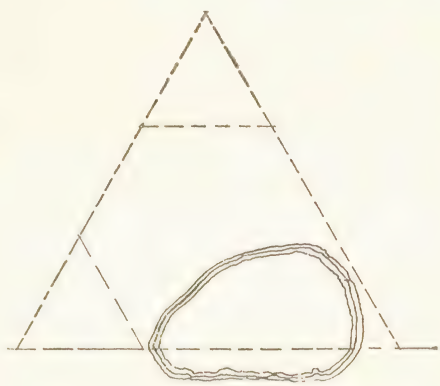


Fig. 45.—Surveying round obstacles. A lake.

MENSURATION USED IN SURVEYING AND LEVELLING

A Point is that which has position but no magnitude.

A Straight Line is the shortest distance between two points.

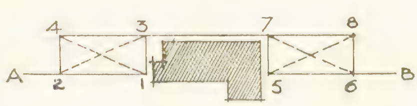


Fig. 46.—Surveying round obstacles. A house

A Level Line is for the purposes of levelling the continuation of the line sighted through the telescope of the level when the air bubble in the spirit level does not move from the centre marks as the telescope is revolved. Actually a level line is one which is always the same distance from the centre of the earth. In ordinary distances levelled, this makes no difference.

A Polygon is a portion of a plane bounded by straight lines.

A Triangle is a polygon having three sides which may be equal or of unequal length.

A Right-angled Triangle is one in which two of its sides form a right angle. The side facing the right angle is called the *hypotenuse*; and the bottom side is called the base, whilst the erect side is called the *altitude*.

An Angle is the space enclosed by two lines meeting at a point.

A Scalene Triangle is one in which none of the sides is equal.

An Isosceles Triangle is one in which two of the sides are equal.

An Equilateral Triangle is one in which all three sides are equal. All the angles of an equilateral triangle are equal also.

A Quadrilateral is a four-sided figure.

A Parallelogram is a four-sided figure in which the opposite sides are parallel. A parallelogram whose sides are unequal and its angles not right angles is called a *rhomboid*; where the sides are all equal, but the angles not right angles, it is called a *rhombus*; and when the angles are right angles, it is called a *rectangle*.

A Square is a four-sided figure in which all the sides are equal and all the angles right angles.

A Pentagon is a five-sided figure.

A Hexagon is a six-sided figure.

A Heptagon is a seven-sided figure.

An Octagon is an eight-sided figure.

The boundary line of any plane figure is termed the *Perimeter*.

A Circle is a plane figure bounded by a line, all points in which are equidistant from the centre of the circle. *The Centre* of the circle is a point within the circle from which all points on the circumference are equidistant.

The Circumference of a circle is the line bounding the circle all points of which are equidistant from the centre.

A Radius of a circle is a straight line drawn from the centre to the circumference—all the radii of a circle are equal.

An Arc of a circle is any part of the circumference.

A Segment consists of an arc and a straight line drawn through the circumference of the circle, cutting it off from the circle.

A Chord is the straight line through the circumference in forming a segment.

A Sector is a figure bounded by an arc of a circle and any two radii drawn to the ends of that arc.

Rule.—The square on the hypotenuse of a right-angled triangle is

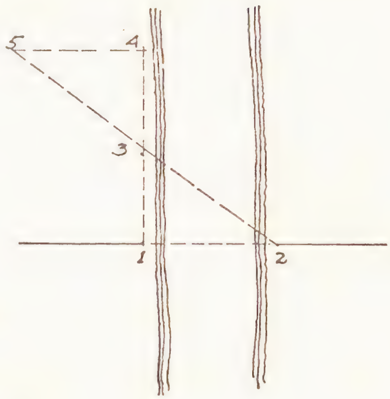


Fig. 47.—Measuring across a river.

equal to the sum of squares on the other two sides. This rule is used in measuring obstruction, such as rivers or lakes over which it is desired to run a base line without actually crossing, as in Fig. 47.

The river is shown in wavy lines, and the base line is marked 1–2, crossing it at right angles. From the point 1 on the bank of the river set out a line at right angles to the base line 1–3 of any measured distance. Then from 3 continue this line 1–3 to 4, making 3–4 equal in length to 1–3. From 4 in the line 1, 3, 4, set out a line at right angles to 1, 3, 4, and on this right-angled line sight a point where 3 and 2 are in line, calling this point 5. (*Note.*—A rod has to be fixed at the point 2, which is the continuation of the base line on the other side of the river.)

Thus, 1, 2, 3 and 3, 4, 5 are right-angled triangles, in which the sides 1–3 and 3–4 have been made equal. Now, as the squares on 3–5 equal the square 3–4 and 4–5, and the square on 2–3 equals the square on 1–3 and 1–2, and 1–3 is equal to 3–4, the distance 2–3 must equal the distance 3–5. Therefore, the distance 4–5 must equal the distance 1–2, which is the desired measurement across the river.

To find the Area of:

A Square.—Multiply the length by the breadth. The same for a rectangle and a rhombus; but for a *rhomboid* multiply the length by the vertical height.

A Triangle.—Multiply half the base by the vertical height.

A Parallelogram.—Multiply the length of any one side by its perpendicular distance from its opposite side.

A Trapezoid (is also a figure which one comes across in triangulating an area when surveying a four-sided figure having two sides parallel).—Multiply the average of the two parallel sides by the perpendicular distance between them. The average of the two parallel sides is obtained by adding their lengths together and dividing by 2.

Any Irregular Four-sided Figure.—Divide into two triangles and multiply half the length of the line drawn by the perpendicular height of each triangle from this line and add the two results together.

To find the Circumference of a Circle.—Multiply the diameter by 3·1416, or for ordinary practical purposes $3\frac{1}{7}$ is sufficiently accurate.

To find the Diameter of a Circle when the Circumference is Known.—Divide the circumference by 3·1416.

To find the Radius of an Arc when the chord and rise are known, square one-half the chord and add the square of the rise. Divide the result by twice the rise, and the result will give the radius.

To find the Area of a Circle.—Multiply the square of the diameter by 0·7854 ; or the square of the radius by 3·1416.

To find the Area of an Irregular Piece of Ground.—The area must be divided into triangles so far as is possible to include the whole. This, for most practical purposes, is sufficiently accurate, as any irregular shape can generally be divided up, so far as the major portion of its area is concerned, into one or more polygons. Then the areas not included in these polygons can be computed by further triangulation, offsets being taken from the lines bounding the polygon.

USEFUL HINTS

Datum.—It is important, in all surveys and levelling, that the measurements and levels taken should have reference to a fixed datum. Wherever possible, this should be the Ordnance Bench Mark, which is an arrow head with a horizontal mark above it. These are usually to be found either on buildings or cut into stones placed specially for the purpose. The centre line of the horizontal mark over the arrow is the actual height corresponding to the level reading on the Ordnance Survey.

Where there are no Ordnance Bench Marks handy, a permanent datum must be established by the surveyor, preferably on some convenient portion of any existing building, such as a step or plinth.

High Walls.—When levelling along a base line which is interrupted by a high wall having no openings in the neighbourhood of the line, the staff should be held upside down with its foot lining with the top of the wall, and level readings taken first on one side of the wall and then on the other. These readings, from the new datum of the top of the wall, are called negative back sights.

The North Point.—This should be drawn on all survey plans. The true north line should be drawn, though the magnetic line at the time of making the survey may also be drawn.

The variation between true and magnetic north is not constant. Both are indicated on the small-scale Ordnance Survey maps with the year in which the variation applies in Britain and the annual decrease. In Britain the magnetic north is west of true north. In some parts of the world it is east.

In transferring a compass bearing to a survey or map, the westerly variation (in Britain) should be added to convert it to a true bearing which may be laid down on the map.

In taking a true bearing from a map, the westerly variation should be subtracted to convert it to the equivalent magnetic bearing.

SETTING OUT AN ESTATE

The survey having been plotted and the contour lines shown on it in the manner described, by lines in different-coloured ink joining the points having the same level, sections along base lines should also be drawn showing the heights at the different station points.

The laying out of the proposed roads should, wherever possible, having regard to the main roads leading to the estate and the most economical use of the land of the estate itself, run in conformity with the contour lines and not across them. This will save considerable expense in excavation, not only for the roads themselves, but also for the foundations of the buildings and for sewers and drains.

The base lines and check lines drawn on the surveying plan should be pegged out again on the site with permanent pegs, and the length of offsets from these base lines to the new roads having been plotted on the plan previously prepared in the office, these also are measured on the site, all the salient points being permanently pegged out. These new lines known as " survey lines " will for the most part form the centre lines of the proposed new roads, and from these the measuring and pegging out of the width of the roads—sewer and drain lines—is a simple matter.

The starting-point in laying out the main base lines of any new estate must be some fixed existing points—such as an existing building—in fact probably the same point or points used in starting the original survey. The first essential is to set out some form of rectangle from these fixed points, embracing as much of the estate as possible. This may, and probably will, leave a corner or corners having no fixed points, and only a boundary of an irregular nature such as a ditch or rough winding hedge. To arrive at the proper laying-out and division of this irregular space, first subdivide the rectangle into as many smaller rectangles as possible, having their sides formed by lines drawn from the centre points of the meeting of the various new roads. Then from these points in the length of the sides of the rectangle a new base line can be established into the irregular area, and by offsets from this the required details can be filled in to scale.

Setting out on small sites can be done with chain or tape and rod. A surveyor's level should preferably be used to put in pegs to give datum level and foundation, floor or other levels. On a large site a theodolite is used to set out angles, base lines and levels.

TABLES USED IN SURVEYING

Linear Measure

Inches.	Links.	Feet.	Yards.	Poles.	Chains.	Furlongs.
7·92	1	—	—	—	—	—
12	1·515	1	—	—	—	—
36	4·545	3	1	—	—	—
198	25	16½	5½	1	—	—
792	100	66	22	4	1	—
7,920	1,000	660	220	40	10	1
63,360	8,000	5,280	1,760	320	80	8 = 1 mile

1 link in a chain = 7·92 inches.
100 links in a chain = 4 rods = 66 feet.
80 chains = 1 mile.

Surface Measurement

144 square inches = 1 square foot.
9 square feet = 1 square yard = 1,296 square inches.
100 square feet = 1 square.

Land Measurement

$30\frac{1}{4}$ square yards = 1 square rod.
40 square rods = 1 square rood = 1,210 square yards.
4 square roods = 1 acre
10 square chains = 160 sq. rods } = 4,840 square yards.
640 acres = 1 square mile = 3,097,600 square yards.
43,560 square feet = 1 acre.

Local Measurement of Land

1 Scotch acre contains 10 square chains of 74 feet = $6{,}084\frac{4}{9}$ square yards = 1·257 statute acres.
1 Irish acre contains 160 perches of 49 square yards = 7,840 square yards = 1·620 statute acres.
1 Lancs. acre contains 160 perches of 49 square yards = 7,840 square yards = 1·620 statute acres.
1 Cheshire acre contains 160 perches of 64 square yards = 10,240 square yards = 2·116 statute acres.

Hydraulic Measure

1 cubic foot of water = 6·23 gallons.
1 gallon of water = 10 lb. avoirdupois = 70,000 grains troy.
1 inch of rainfall = 22,622 gallons per acre.

French Equivalents

1 metre = 39·37 inches.
1 kilometre = 1,093·62 yards.
1 hectare = 2·471 acres = 100 ares.
(An *are* is a square, each side of which is 10 metres.)

HEDGES AND BOUNDARIES

The measurements should be taken to the centre of the roots of hedges wherever this is possible. The ownership in the matter of hedges and ditches is taken as belonging to the owner of the property as extending to the ditch + 3 feet, as in Fig. 48, A, the assumption being that the ditch was dug on the boundary of the land and the soil thrown up on to the owner's own land and the hedges planted on the top of the mound so formed. Where there is no ditch the boundary is taken as being the line running along the centre of the hedge.

A boundary against a building is usually in vertical line with the eaves projection, as in Fig. 48, B.

Fences are presumed to have been erected on the owner's land with the

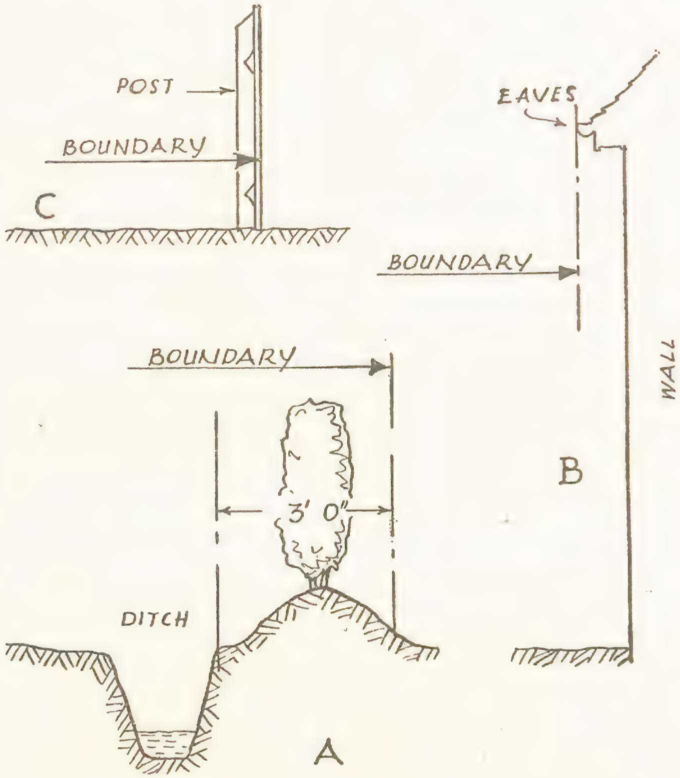


Fig. 48.—Common boundary features.
A. Ditch and hedge. B. Overhanging eaves. C. Board and post fence.

paling on the boundary line nailed towards the owner's land. They are marked on estate plans thus ——T—— (Fig. 48, C).

The Centre Line of a stream or river is taken as being the boundary. But neither owner has the right to interfere with the flow of water in his part of the river.

CHAPTER 4

ROAD CONSTRUCTION

THE following are the chief systems of road construction :

(*a*) Macadam, with water-bound, tar, bitumen, or cement-bound surfacing on hardcore foundation.

(*b*) Concrete foundation with surfacing or paving.

(*c*) All concrete, usually reinforced, with no separate surfacing material.

MACADAM

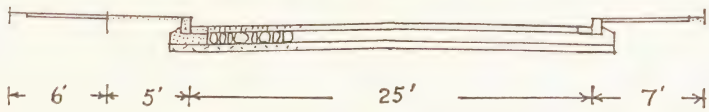
The first step in laying a macadam road will be similar to that for other roads. It is, in fact, more important that the drainage of surface and subsoil water should be undertaken with thoroughness, as macadam is water-bound, and any undue quantity of surface water after the road is laid will tend to weaken this binding. The excavation and shaping are undertaken in the same manner for the roads as already described in Chapter 2. Over clay, or other non-absorbent subsoil, from 3 to 6 inches of clinker or engine ashes should be laid in. Upon this lay a large hand-set pitching of stone, slag, hardcore or other hard rubble. This should be tightly wedged with small material and rolled to an even contour. The thickness of this pitching is usually not less than 12 inches to suit the requirements, as shown in Fig. 49.

Water-bound Metalling.—The three important requisites for the stone surfacing known as metalling are toughness, chemical durability and binding capacity. The first, toughness, must be distinguished from hardness, as it is required that the stone should resist wear. Many hard stones are also brittle, causing them to break under constant traffic conditions. Chemical durability is the property which a stone possesses to resist the change of atmosphere. The most necessary quality in a good binding stone is that which causes the stone to preserve its angular form rather than to wear round and smooth. The stone dust produced by wear is best also when it forms a cement which assists in the binding action. The thickness or depth of metalling necessarily depends upon the traffic requirements. Some parts of the main roads were in the old days metal to a depth of 12 inches. However, for most ordinary traffic a depth of 4 inches is sufficient.

In spreading the stone, skilled labour is desirable, as a uniform spreading is required, and screenings used as top dressing during rolling operations must be evenly spread and with due regard to the spaces left in the under-metalling. These screenings are obtained by sifting through a $\frac{3}{4}$-inch rod screen, and the metalling should vary from 2 inches to $2\frac{1}{4}$ inches

The roller required for consolidating the macadam should be at least a 12-ton roller, and the rolling should start from the side and finish at the centre, the final surface having a camber from centre to side of one in forty.

Though water and binding material are necessary, as already stated, being spread-watered and swept over the surface during the final rolling



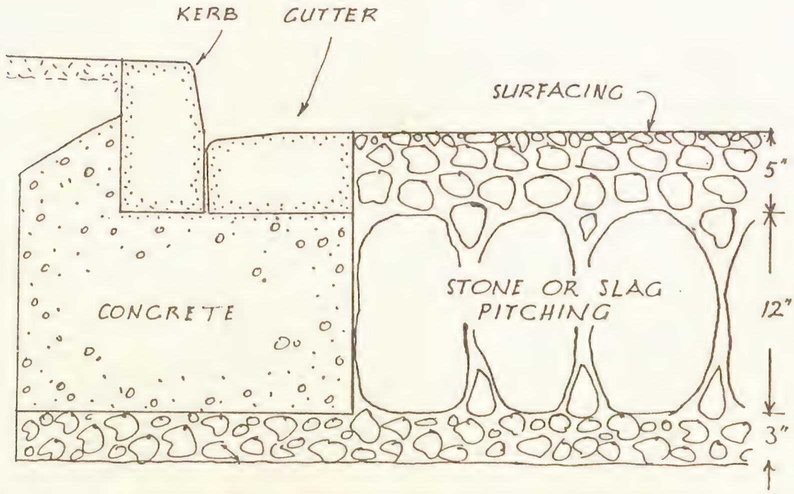


Fig. 49.—Cross section of road with stone or slag pitching and macadam surface.

operations, no water or binding material should be supplied until the dry metalling has been well consolidated. It is in the final watering that the skill and experience of the workmen are requisite, as too much of either of these, water or binding material, will upset the proper consolidation.

TAR AND BITUMINOUS MACADAM

These surfacings have now largely superseded water-bound macadam. There are various types for hot or cold application, pre-mixing or direct surface application. There are several well-known proprietary road surfacings based on these types.

The Foundation.—This may be—

(*a*) A pitched foundation of a single or double layer of stones on a sub-foundation of hard furnace clinkers.

(*b*) A concrete foundation, reinforced with metal fabric, on a sub-foundation of hard furnace clinkers, broken stone or brick hardcore.

Foundation (*a*) is formed, after excavating and laying drains and sewers, by first laying the sub-foundation of suitable clinker, broken stone or brick, or slag hardcore, with a certain amount of fine material to fill crevices, to a finished depth of 3 inches to 6 inches according to type of ground and traffic to be carried. This is spread, levelled and rolled, the weight of roller being 1 ton for each 1-inch thickness.

On this the foundation proper is laid. This consists of stone "pitching" laid to a depth of 8 to 12 inches. The stones are laid on edge, and they should be fairly uniform in depth. They should be about 12 inches long by 5 inches wide by the depth of the foundation. They are properly laid by hand across the road in parallel lines to break joint, and are firmly wedged together by pushing thin stones in between, using a pinch bar to open a gap for the insertion of the stone wedges.

Alternatively, broken stone of smaller size can be spread and rolled in two layers as follows:

The bottom layer should be 5 or 6 inches finished thickness, consisting of 4-inch-gauge broken stone spread and rolled. The upper layer should be 4 or 5 inches finished thickness, consisting of graded broken stone (graded from very small pieces to the full 4-inch-gauge material). This should be rolled with a roller of 8 tons weight to give a well-consolidated face of proper camber.

Tar and Bitumen Macadam.—The surface is finished with tar or bitumen macadam, consisting of an aggregate of whinstone, granite, limestone or slag coated evenly with hot tar or bitumen, using 8 to 10 gallons per ton of aggregate.

The aggregate should be graded as follows:

One-third	$2\frac{1}{4}$ to $1\frac{1}{2}$-inch gauge.
One-third	$1\frac{1}{2}$ to $\frac{3}{4}$-inch gauge.
One-third	$\frac{3}{4}$ to $\frac{1}{4}$-inch gauge.

The makers of the tar or bitumen supply instructions for heating and mixing, but there are many specialist firms which contract to supply, lay and roll the surfacing.

Asphalt.—This is used for road surfacing in the form of a coarse carpet coat, consisting of broken stone or slag graded from $\frac{3}{4}$-inch down to $\frac{1}{8}$-inch gauge with finer material as a filler, heated and mixed with the hot asphaltic binder. The mix is then spread and rolled to a finished thickness of 1 inch. This gives a cleaner and harder wearing surface than macadam.

Surface Dressings.—Tar or bitumen surface dressings are now widely used for surfacing existing roads. The tar or bitumen is applied, after all loose material has been brushed off the old surface, in the proportion of 1 gallon to 4 square yards. Crushed gravel $\frac{5}{8}$-inch gauge is then thrown evenly over the surface and rolled in. The treatment should be repeated a few days later.

Cold Surfacings.—Tar and asphalt and emulsions of these materials are available for cold application. There are various processes which are described in current British Standard Specifications. As with hot surfacings, there are many firms specialising in the application of these cold surfacings who contract to lay and finish the surfacing.

Equipment.—Special trucks, road vehicles with spraying equipment, heating equipment, and tools are made for handling hot and cold tar and bituminous road materials.

REINFORCED-CONCRETE ROADS

The ground must first be excavated to the necessary depth as for other roads, and graded to the cross falls for the finished road surface. The most suitable cross fall is 1 in 48, and this grading ensures economy in the quantity of the concrete required.

For subsoil likely to retain water, drains must be provided at the sides at a minimum depth of 18 inches below the surface of the excavated

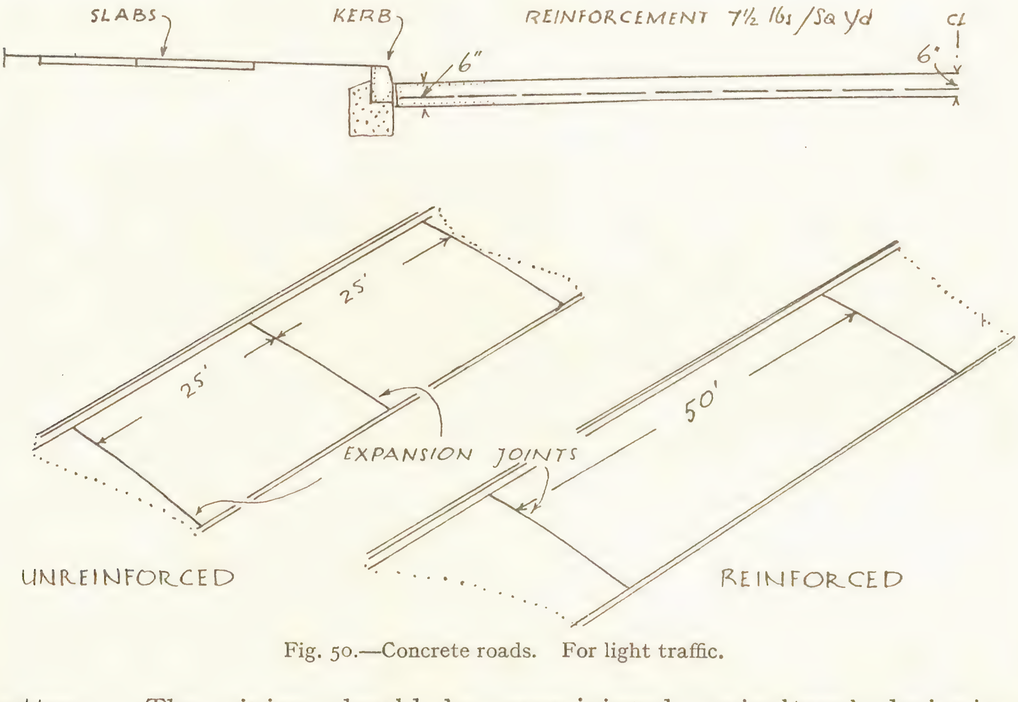


Fig. 50.—Concrete roads. For light traffic.

bottom. The piping should be open-jointed agricultural drainpipe, and the trench filled in with stones to prevent soil entering and choking pipes.

To aid in the drainage of the roadway underneath the concrete, it is advisable to lay and consolidate 3 inches of hard broken bricks or furnace clinker.

The filling in should be carried out in layers of not more than 12 inches

in thickness and each layer should be thoroughly consolidated before the next is applied. For this work a heavy horse roller, of about 2 tons, is most suitable.

Previous to the laying of the concrete, the filling and the subgrade should be well soaked with water until they are saturated. On this, lay screeds of concrete $1\frac{1}{2}$ inches thick and 4 inches wide every 4 feet apart.

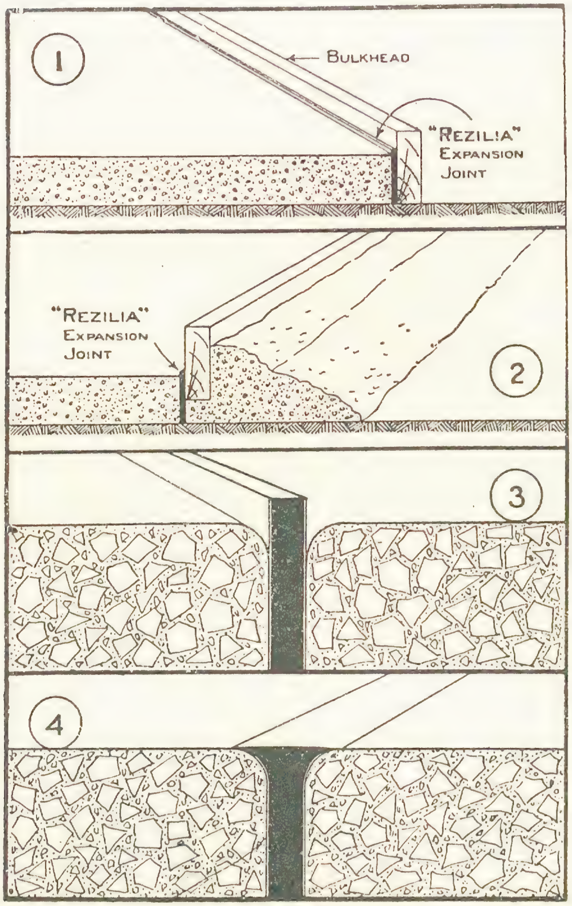


Fig. 51.—" Rezilia " expansion joint. Stages of installation.

1. Joint supported by end form of bulkhead. 2. Form gradually lifted as concrete in adjacent bay is poured. 3. Edges of concrete trimmed as a precaution against abrasion. 4. Joint completed by compressing projecting portion into position.

On these concrete screeds a metal reinforcement is then laid, such as 6-inch-mesh expanded treble-layer reinforcement, or a steel-wire mesh fabric, as shown in Fig. 50.

The concrete is then laid and well rammed around the reinforcement so as to embed it completely. If possible the concrete should be completed across the whole width of the roadway in one operation. In making joints, these should be finished diagonally across the road, and on starting work again, the edge of the joint should be thoroughly wetted and dusted with dry cement. The work may proceed in alternate bays (*i.e.* between screeds) at a time, which method is often adopted as a precaution against surface cracking, but it is not reliable, as explained later. Expansion joints must be formed along the edges of the road against the kerbs, by inserting $\frac{1}{2}$-inch wrought boarding, well greased before insertion. As soon as the concrete has set, these boards should be removed and the space filled with a plastic compound.

As soon as the surface is sufficiently set, cover with a 2-inch thickness of sand, and keep wet for a period of at least ten days. Traffic should not be admitted to the road until twenty-one days after the finish is set, unless one of the rapid-hardening cements has been used.

Thickness and Reinforcement.—For light traffic in residential service roads a minimum thickness of 6 inches is usual. For heavier traffic 7 or 8 inches may be necessary.

On a very good natural foundation no reinforcement is necessary, but usually for estate roads single reinforcement of $7\frac{1}{2}$ pounds weight per square yard is adopted. For heavy traffic or a poor foundation top and bottom reinforcement is adopted.

Expansion Joints.—A continuous concrete slab road will form cracks due to shrinkage and thermal movements. This can be avoided by

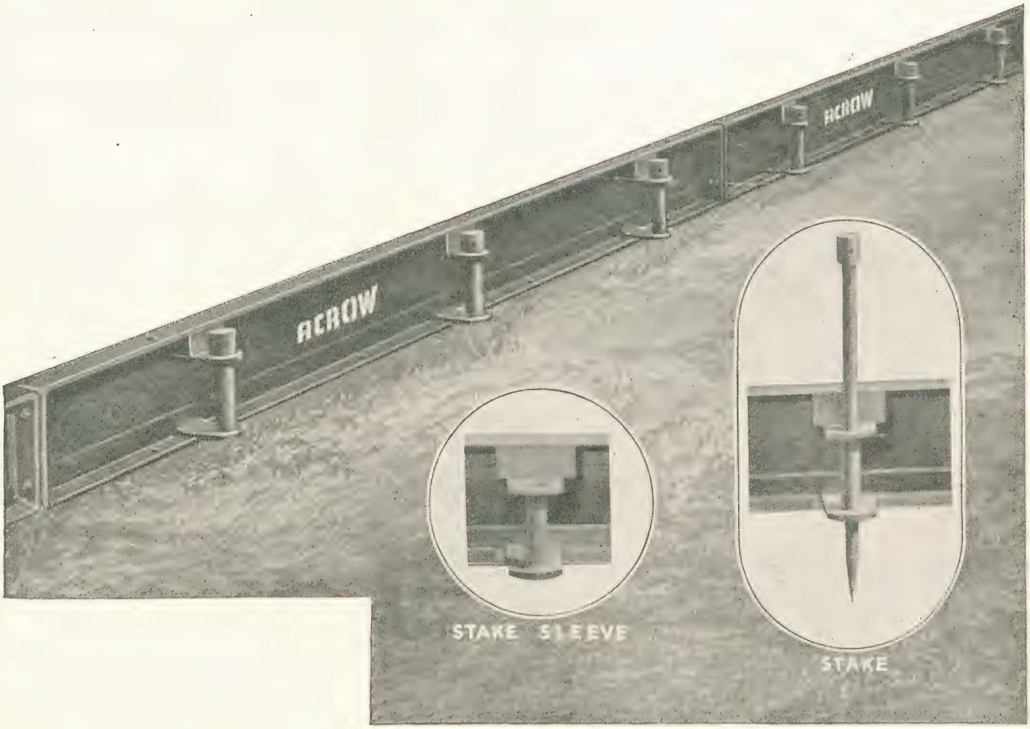


Fig. 52.—Acrow steel road forms.

Standard length, 8 ft. Five depths : 5, 6, 7, 8 and 9 inches. Quickly fixed and removed for reuse. Each form has three steel stakes. End-to-end lock jointing gives perfect alignment. (Acrow (Engineers) Ltd.)

dividing the slab into bays by means of expansion joints filled with a resilient mastic as shown in Fig. 51. The expansion joints should be spaced about 25 feet apart if the slab is not reinforced, and 50 feet apart if it is reinforced with at least $7\frac{1}{2}$ pounds of steel per square yard. This is illustrated in Fig. 50. For joints up to 25 feet apart the joint thickness should be $\frac{1}{4}$ inch, and up to 60 feet apart $\frac{1}{2}$ inch. There are several proprietary expansion jointing materials, some being in the form of solid strips inserted as shown in Fig. 51. Asphalt can also be used for this purpose.

Expansion joints should also be provided between the edges of the slab and the kerbs. With slabs wider than 20 feet, longitudinal cracking must be avoided by having longitudinal expansion joints. With wide roads these are placed not more than 15 feet apart.

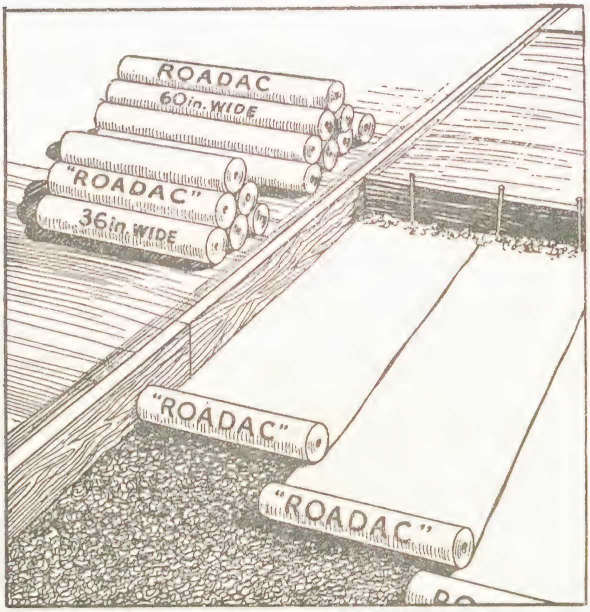


Fig. 53.—Waterproof building paper laid over ground to protect concrete from ground impurities and absorption of moisture. (The Concrete Tool Supply Co.)

Concrete Proportions.—For estate roads the slab may be laid in one thickness 4 : 1 mix. Alternatively a foundation layer 5 : 1 or 6 : 1 may be laid at least 5 inches thick, and followed by a 2-inch surfacing layer of $3 : 1\frac{1}{2} : 1$ mix. The surfacing layer should follow the foundation layer within half an hour.

Clean materials and hard non-dusting aggregates are essential. A good hard-wearing mix consists of 3 parts 2-inch granite, $1\frac{1}{2}$ parts $\frac{1}{4}$-inch granite, $\frac{3}{4}$ part of sand, and 1 part Portland cement.

Laying.—Wood plank forms firmly secured with wood pegs can be used to hold the edges of the concrete slab. Special steel forms are now largely used, as shown in Fig. 52. These are quickly and accurately fixed and readily removed for reuse.

Waterproof building paper may be laid on the surface of the ground to protect the concrete from ground impurities, and to prevent the ground absorbing the moisture. It is essential to " cure " the concrete ; that is, to prevent rapid drying out. Waterproof paper can be used for this purpose also, instead of sand or sacking, which needs frequent damping.

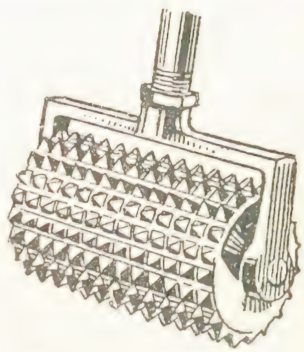


Fig. 54.—Concrete roller for indenting pattern on concrete or granolithic paving. (T.C. Jones & Co. Ltd.)

Consolidation by tamping is an important feature of good practice. Suitable tampers consist of 9×3-inch pine with the bottom cambered edge having a $3 \times \frac{3}{16}$-inch mild-steel flat screwed to it, and handles fitted at the ends. The tamper should be the width of the bay. Tamping should be carried on just long enough to properly consolidate the concrete, but not long enough to draw too much fine material to the surface. Tamping leaves small parallel ridges which

give a good non-skid surface, though rather too rough for comfort. The ridges can be removed by using a smoothing board. The board should be drawn over the surface twice only. A straightedge should be used at the same time so that any transverse " waves " can be smoothed out. Excessive smoothing is harmful, as it produces a slippery surface and draws too much fine material to the top. Such fine material easily dusts up.

Hardening.—To achieve maximum durability and to prevent any possibility of dusting up, a chemical hardener may be used. There are several proprietary makes, but a solution of P 84 sodium silicate is as good as anything. It is brushed or mopped over the surface.

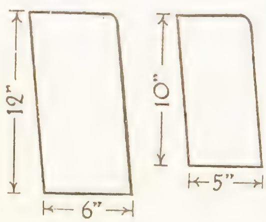


Fig. 55.—Pre-cast kerbs. This is the battered section; other patterns are made. (Tarmac Ltd.)

CEMENT-BOUND ROADS

The following description is from *The Concrete Year Book*:

" Cement-bound macadam roads, as their name implies, are roads constructed on the macadam principle but with a cement mortar as the matrix. There are two methods in use, (*a*) grouting, (*b*) the ' sandwich ' principle. It is essential to success that the work be carried out on a well-consolidated foundation such as an existing road surface.

" In the grouting method, about 4 inches of 2-inch metal is spread and lightly rolled to camber. A 1 : 2 cement-and-sand slurry is then brushed over the surface and rolling is continued till the surface is true and free from undulations.

" The following is the procedure with the ' sandwich ' method. After the foundation has been prepared and shaped, a layer of 2-inch stone is lightly rolled with a 6-ton roller to a depth of about 2 inches. On this is spread a layer of 1 : 2 cement mortar to a depth of $1\frac{1}{2}$ inches. The top layer of stone is then spread and rolled, and rolling is continued not only until the mortar is thoroughly worked through, but also until the road reaches the correct profile and is free from undulations. The surface is then brushed to ensure even distribution of the mortar and expose the stone so that the finished surface resembles that of water-bound macadam. Where the work is carried out on steep gradients, brushing is continued till each stone stands slightly proud, thus providing a non-skid surface and a foothold for horses.

"Each day's work is finished off to a vertical face by rolling up to a heavy baulk of timber 4 inches thick. Before the next day's work is begun it is common practice to insert a strip of bituminous filler $\frac{1}{8}$-inch thick against this face. Rolling should stop about 6 inches short of the previous day's work, the space unrolled being consolidated with hand tampers to avoid dislodging stone in the green concrete of the adjacent bay.

"The materials required per 100 square yards are: Stone (2-inch B.S. gauge), 15 tons; sand, $4\frac{1}{2}$ tons; cement, $1\frac{7}{8}$ tons. With one roller and driver and ten men, from 300 to 350 square yards can be laid in a day.

"The cost depends on local conditions, as a reasonably hard and tough stone is required which may have to be transported considerable distances. In favourable circumstances the cost has been as low as 2*s.* 6*d.* per square yard. The cost can be reduced if a cheaper stone is used in the bottom layer, but even so it must be sufficiently hard to resist crushing by the roller. This form of construction is particularly adaptable to secondary roads, and the rugosity of the surface and the resistance to scouring make it particularly useful on steep gradients."

THE DRAINAGE OF ROADS AND DRIVES

The drainage of roads and drives should never be neglected, as on its successful accomplishment depends not only the accessibility of the road or drive, but also its permanence and durability. At each side of the roadway before the hardcore is laid in there should be trenches dug to a depth of 3 feet below the excavated bottom. In these trenches agricultural drainpipes of requisite dimensions—a 3-inch pipe being the minimum—must be laid dry. Over these pipes lay in brushwood bundles and then cover with hardcore or gravel. The excavated surface should then be rolled with a roller of not less than 2 tons weight, after which the hardcore should be spread to a thickness of 18 inches. This consists of either broken rock, broken brick, rough clean gravel or burnt clay—no stone or piece of aggregate larger than 3 inches being left unbroken. This ballasting of hardcore should be continued from end to end of the new roadway and the curved-in section (the camber), having a rise of at least 6 inches from the edges to the centre or crown. The whole should be then watered and rolled, a certain amount of fine gravel being spread and rolled in after the hardcore has received its first rolling, to settle it in and bind it against the casting which is to pass over it during the building operations.

SURFACING

After the completion of the building works there will be found to be sinkings and pot-holes in this hardcore surface. These should be filled in level. For driveways and roads which are to carry only light traffic, a surface coat of burnt clay, gravel or cinders, not less than 6 inches

deep, should then be spread, care being taken to maintain the camber or curve from sides to crown. Water well and roll, with the roller following close upon the water cart. Then spread a fine gravel mixed with sand. watering until of the consistency of a grout which must be swept with stiff garden brooms, back and forth, until all interstices are filled. Cinders alone do not make a very satisfactory surfacing, but should be sprayed with tar. This provides a very durable surface, but its colour is not the best that is to be obtained—for a private driveway.

There are specialist firms in every district who contract for making paths, drives and pavings. Cold tar or bituminous macadam is largely used for wheeled traffic, and pre-cast slabs for paths and pavings.

Slabs should be bedded in lime mortar at the corners only to prevent the development of wobble.

For more permanent roadways a surfacing of 9 inches of granite finished with fine chips should be formed by well watering, rolling, again watering, and breaking as before described.

In width a driveway should be not less than 10 feet for its main length, though if passing points are formed and it is particularly desired to save expense, a width of only 5 feet may be found to serve. However, in laying out roads of such slight widths, thought should be given to the extra width required at any turns or angles. In fact, if such occur in the length of a drive or roadway, it is at such points that passing widths should be provided. A double road round a central bed will be found to give what is required at a cost that will not add very materially to the total outlay.

COST OF ROADS

It should be noted that whilst the cost of the construction of roads is borne by the owners or lessees of the land and frontages, the cost of maintenance, after the roads are taken over, becomes a charge on the local authority. Consequently, it should be ascertained by anyone laying out an estate whether the roads are to be taken over by the local authority or not, and if they are, at what point in the development of the estate this is to be the case. It will be appreciated that where roads are to be later taken over by a local authority, the natural result is that there is a desire to reduce as much as possible the expense in upkeep that will fall upon that body, consequently a greater demand is made upon the person or body laying out the estate, in the matter of the initial expenditure on the roads.

The local authority usually provides a specification which must be worked to. The road must be approved by the authority's surveyor before it is "adopted," and the owner relieved of responsibility for its upkeep.

FORECOURT

For turning in front of houses there will be required a forecourt of at least 35 feet diameter if circular. There should be no stinting in this

matter, as the effect of reversing and pulling up will be found, in the long run, to be more expensive than the cost of additional width in this area ; and as has been already explained, a saving where required can be effected much more serviceably to the purpose of the entrance drive by reducing the width of its main length and providing passing points therein.

PATHS

On a site in the country or suburbs, a certain amount of path formation will be required, in connection with which there are a few points additional to the matter already detailed which should be noted. Whilst it may be considered that garden design is not part of the work of the building contractor, yet the formation of paths, at least, will be found to enhance the value very considerably and out of all proportion to the cost to the contractor.

The most usual, and in many ways the most satisfactory, garden path is that composed of gravel. Its construction is practically the same as that already explained for roads. The direction of the path having been pegged out, the top soil must be excavated to a depth sufficient to give a bottom of more or less firm subsoil, though, as the weights to be borne are not so great as those carried by a road, the excavation will not require to be so deep in most instances. The excavation should then be filled in with hardcore of a smaller size than that used for roads, and over this from 3 inches to 6 inches of gravel should be laid, deeper in the centre of the path than at the edges. Though the camber given should not be as great as that in the formation of roads, as a path with an excessive camber is uncomfortable to walk on and unsightly, yet a fall to the sides should be given.

An important point in the laying out of garden paths is that they should take a direction to serve some obvious purpose, otherwise use will cause corners to be cut off, clearly proving that the initial layout must have been at fault.

Except for unusually wide paths, a single drain at one side—*i.e.* the lower side in the course of the natural flow of subsoil water—will be sufficient. This should be constructed as for roads, but a 2-inch to 3-inch agricultural drainpipe will usually be found sufficiently large, as in Fig. 56.

In heavy soils, such as clay, the foundation of hardcore will require to be thicker than in light sandy soils, otherwise the clay subsoil will work up to the surface sooner or later.

Pavings to Paths.—For garden paths bricks are laid flat on a levelled ground, over which a drainage material such as ashes covered with sand has been spread. The bricks are laid in a stretching bond, the joints being left open and filled with sand or soil. For paved areas, the bricks must be set on edge and jointed with cement mortar. Brick edgings are also formed to paths, either brick on edge or on end, set canted to give a toothed finish to kerb.

Roads are also paved with bricks, but the practice is not often adopted in England, and is very rarely seen in entrance drives to houses.

Crazy Paving, in Gloucester or Purbeck stone, is growing in popularity for garden paths, and though the initial laying may take longer than other finishes, the method, when the area covered is considered, is not an expensive one. As with other surfacings a drainage hardcore or foundation must be laid in, when the crazy paving may be laid on either sand or cinders. If it is desired that plants should grow in the joints,

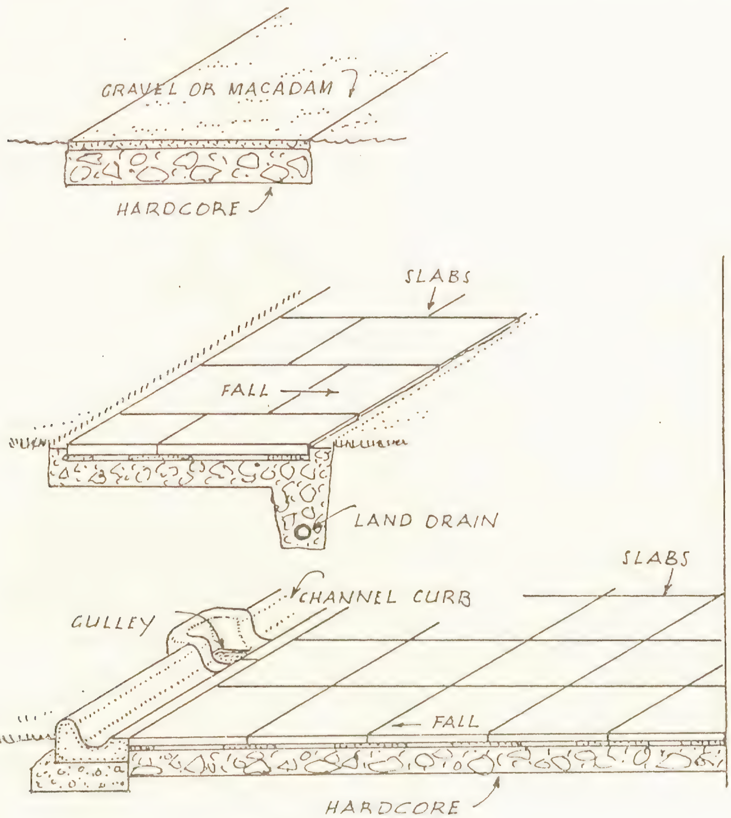


Fig. 56.—Paths and paving.

these must be filled with fine loam. The cost of crazy paving is mainly that of carriage, which will depend upon the distance of the district from the source.

Concrete Crazy Paving.—A cheaper and quite satisfactory form of crazy paving is to be obtained from laying in concrete with moulds of various irregular shapes from 2 inches to 3 inches in depth. As soon as the concrete is set, the moulds are struck and the slabs stacked to cure, when they may be used in the same manner as the stone paving.

Concrete Paving Flags are clean, cheap and easily laid, and prevent

weeds growing through. The proportions of the ingredients used are as follows: Portland cement, 1 part; sand, $1\frac{1}{2}$ parts; coarse aggregate, graded $\frac{1}{2}$ inch to $\frac{1}{8}$ inch, $2\frac{1}{2}$ parts.

Firms making pre-cast concrete products produce these slabs in better quality and at least as cheap as they can be made by the builder. Standard sizes are 2 feet wide by 1 foot 6 inches, 2 feet, 2 feet 6 inches and 3 feet long, by $1\frac{1}{2}$ inches, 2 inches and $2\frac{1}{2}$ inches thick. They are obtainable in grey, buff, red, brown and green.

Wide Terraces and paved areas should be laid with a cross fall with a drainage channel or gutter along one or both edges. Fig. 56 (bottom) shows a channel formed with pre-cast concrete units with a kerb.

CHAPTER 5

SHORING, TIES, UNDERPINNING AND HOARDINGS

SHORING

WHERE a new building is to be erected on a site situated between sites already built upon, the walls of the existing buildings will require to be supported before any operations are commenced on the new building. Should there be a building already occupying the site, which must be removed, it may be necessary to afford such support to the adjoining buildings before the old building is taken down. Should there be a party wall dividing the two buildings, this will require special work, which must not be undertaken until notices have been served and the required time has elapsed.

Raking Shores.—Where a building which has abutted on to another is removed, the thrust exerted on the party wall tends to overturn that wall in the direction of the building removed. To counteract this, shores inclined at an angle are erected from the ground to the standing wall. These are called Raking Shores and are of a composite form. This composite form is rendered necessary by the fact that the greatest thrust outwards on the existing wall is occasioned at those points at which the floors cut the wall. Consequently it is to these points that the different members of the shore are extended.

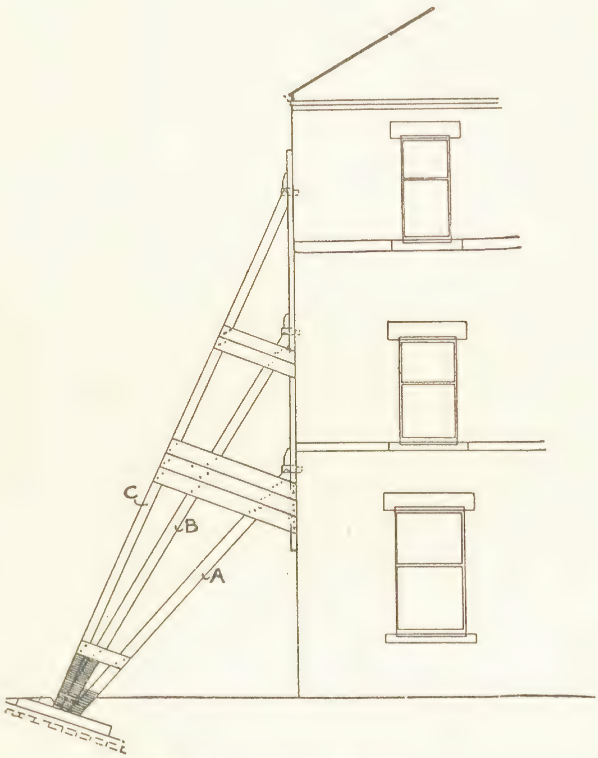


Fig. 57.—Raking shore.

Where an existing building is to be removed and a new excavation required in its place, the raking shores must be constructed before the

supporting walls of the existing building are removed. These shores must also rest their feet upon the ground or some other support which can be retained in position until the whole of the building is removed. Pits or shafts are then sunk to the required depth of the new excavation and other raking shores erected from the bottoms of these before the whole area may be excavated.

Raking shores are also required where a building shows signs of overturning, caused by sinking of the foundations, though this movement must be distinguished from the cracking in a wall which denotes sinking, pure and simple. In this last, a Dead Shore is required, as will be found described later. The front walls of houses may be shored by raking shores where the width of the street permits, but a licence must first be obtained.

Where the width of the street is not such as will permit of raking shores and the width of the site between two existing buildings is not more than 40 feet, another type of shore is used, known as the Flying Shore. This, extending horizontally between the two adjoining buildings, leaves the site free and undiscommoded for building operations.

The Construction of Composite Raking Shores.—As has been said, the purpose of the raking shore is to offer resistance to a movement tending to overturn a wall ; and as the points at which these stresses are chiefly exerted are where the floors and roof timbers rest on the wall, the shore is constructed of several members leading from the ground to those points. Thus a system of shores is built up, having as many raking members composing it as may be requisite. Whilst the main purpose of the raking shore is to resist overturning, the need for such resistance may be caused by sinking of the foundations. That is to say, the sinking results in a tendency in the wall to fall outwards. Thus it is necessary to pin the top end of each member of the composite shore into the wall, thereby at the same time as the overturning is prevented the direct downward movement is checked by the weight on the foundations being relieved. In this manner, both the characteristics of a horizontal and a vertical shore are combined in the raking shore.

In order that the resistance of the shore to the overturning stress may be distributed over the surface of the wall, a wall piece is laid vertically on the wall. Through this, at the points of contact of the raking shores, needles pass through holes cut to receive them and into the brickwork of the wall. The resistance of these needles is strengthened by cleats fixed above them and in the head of the shore is cut a notched shoulder. To enable the wall piece to be retained in position during the construction of the shore, it is cleated to the wall by wrought-iron wall hooks, which are driven into the brick joints and clasp the wall piece to the wall.

The needles, which are notched down to 3 inches to take the cleats, are then driven 4½ inches into the brickwork through the mortices cut to receive them in the wall plates. The cleat, which is of a bevelled pattern, is then fitted down into the notch in the needle and spiked to the wall piece.

For the feet of the shores to rest on and to distribute the pressure over a greater area a sole plate 9 × 4 inches from 2 feet 6 inches to 3 feet in length is introduced at the right angle. In loose or soft soil, this may require the insertion of an additional platform underneath it composed of 11 × 3-inch planks run at right angles to the sole piece. Where the soil is very unstable, or there is to be excavation around the shore, already

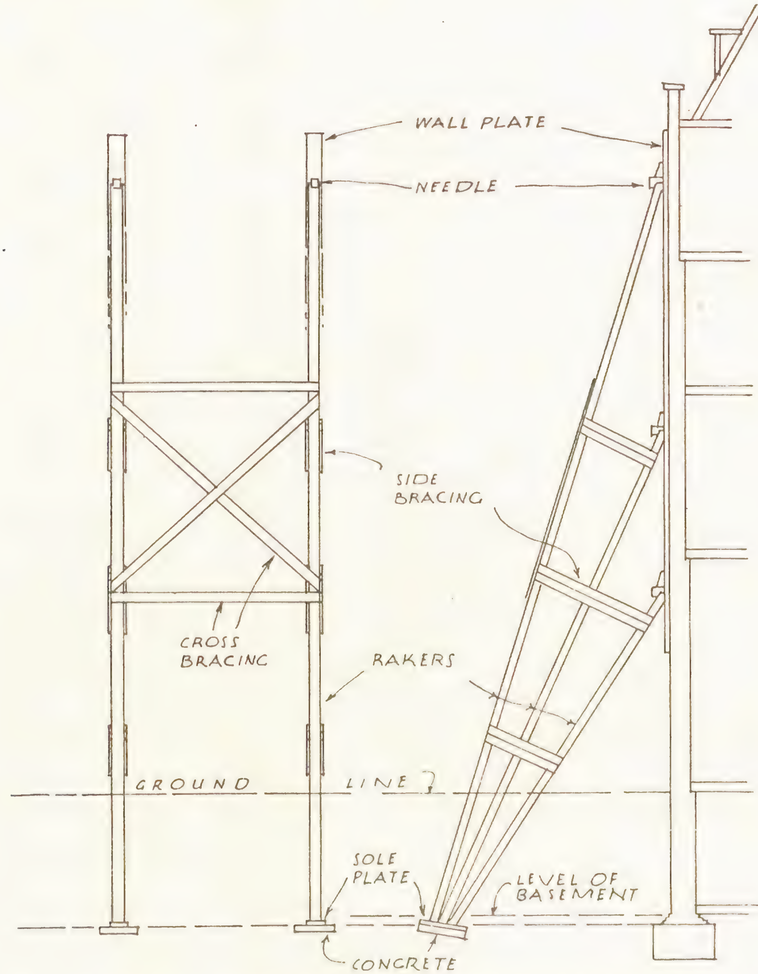


Fig. 58.—Multiple raking shore. The elevation on the left shows two sets of shores cross braced.

referred to, a concrete foundation may be required under the sole piece. The angle at which the sole piece is set in the ground is a little less than 90° to the uppermost shore, so that a crowbar can be used to tighten the shore as in Fig. 59.

Setting out Raking Shores.—This can be done by two methods: (*a*) by making a large-scale drawing and taking off lengths and angles; (*b*) by taking lengths and angles direct from the site.

By method (*a*) accurate levels of the ground in relation to the wall must be obtained. Positions of floors behind the wall are also necessary. The drawing should be made on a scale of at least 1 inch to 1 foot. This enables the lengths to be measured with sufficient accuracy. The

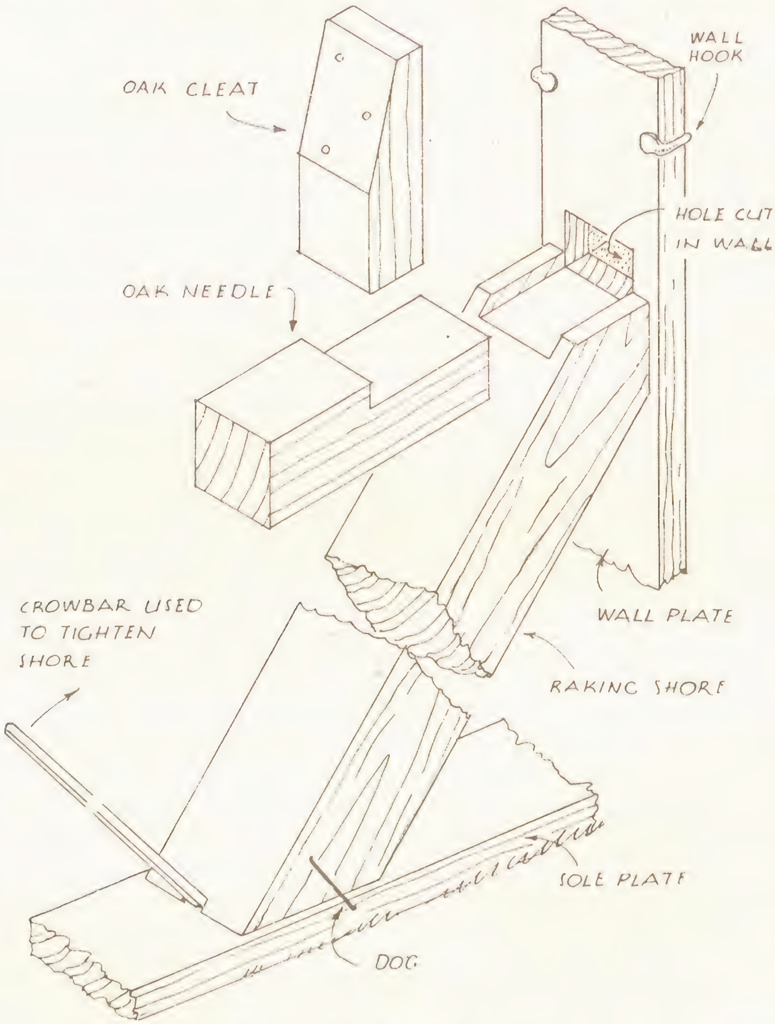


Fig. 59.—Details of raking shore.

angles at foot and head of rakers may be traced off and then transferred to a thin board which can be cut out to form a templet.

In setting out rakers the centre line running up the axis of the raker should intersect the floor bearing as shown in Fig. 60. In this position the raker will best meet the thrust of the floor, and, indeed, the floor will take the thrust of the raker, for it is as dangerous to allow the shore to thrust the wall inward as to allow floors or other loads to thrust the wall outward. For this reason, in some cases raking or flying shores

may have to be erected both inside and outside so that the wall cannot move either way.

The sole plate under the foot of the raker must rest on an adequate foundation. A grid of sleepers can be formed, or a concrete foundation. This foundation should be at least a foot below ground level. The internal angle formed by the sole plate and the raker should be less than 90°, so that the raker can be tightened against the plate by moving it up with a crowbar as shown in Fig. 59. It is then secured with a dog. In setting out the depth and angle of the sole plate must be allowed for.

By method (*b*) no drawing is necessary, though even a small-scale drawing is useful in deciding the angles and centre lines of the rakers. The position of the needle at the head of the raker is first decided, bearing in mind that the centre line of the raker should intersect the centre of the floor bearing on the wall. The position of raker foot is then decided, and a line is stretched from the centre of the raker foot position to the needle. This represents the centre line of the raker. The foot and head angles can then be marked against the line on a thin piece of wood which is afterwards sawn out to form a templet. The length of the line gives the length of the raker along the centre, but care must be taken to allow for the thickness of the wall plate and the sole plate.

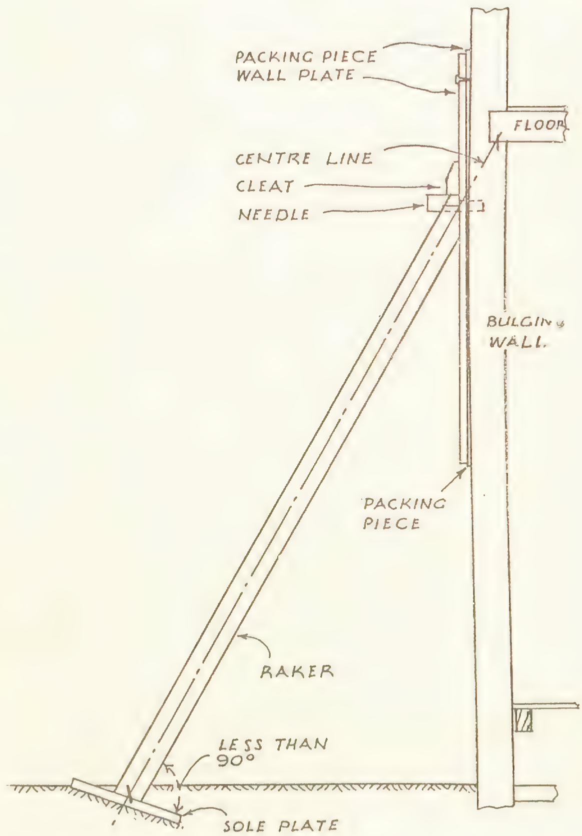


Fig. 60.—A single raking shore supporting a bulging wall.

Erecting Raking Shores.—The number of raking shores required can only be determined by an experienced man after inspecting the wall and the floors, etc., on the inside.

It is not usually necessary to have a raker for each floor. One for every alternate floor is sufficient if the wall is fairly strong. The sets of shores should be 10 feet to 18 feet apart.

Over-shoring may be dangerous if the wall is weak. A multiple shore exerts considerable thrust and, as already stated, this thrust must be met

by floors or other internal members. Otherwise the shores may thrust the wall inwards.

To erect a multiple shore, first set out the positions of the needles—on header bricks if possible. These must be plumb. Cut out the headers to a depth of $4\frac{1}{2}$ inches. By measurement or marking on a rod these positions can then be transferred to the wall plate and the needle holes cut. The plate is then hoisted into position and secured with wall hooks. The needles are placed in the holes. The sole plate is bedded (after preparing any foundation considered necessary). The raker, being cut to length with correct head and foot angles, is then hoisted into position, erecting the lowest raker first and working upwards. Tighten each raker with a crowbar as in Fig. 59. For this purpose the sole plate must make an internal angle with the raker of less than 90°—say 80°. Then secure the foot of the raker with an iron dog on each side.

Do not over-tighten the rakers, as this will create too much thrust against the wall. When tightened, brace the sides with wide boards at least 1 inch thick and cross brace the sets of shores together as shown in Fig. 58.

If a new basement forms part of the new building the shores must be taken down to basement level as shown in Fig. 58.

Sizes of Raking Shores.—Shores up to 15 feet apart—longest:

Length of raker.	Minimum section.
Up to 25 feet	4 inches × 4 inches
Up to 35 feet	6 inches × 6 inches
Up to 50 feet	8 inches × 8 inches
Up to 60 feet	9 inches × 9 inches

Wall plates should be 3 inches wider than rakers and 2 inches or 3 inches thick.

Sole plates should be 3 inches wider than rakers and 3 inches thick, with foundation as necessary.

Needles of oak $4\frac{1}{2}$ inches by 3 inches for smaller shores, and 6 inches by 4 inches for larger.

Cleats of oak same width as needles and 3 inches thick.

Bracing the rakers, to stiffen the composite structure, is effected by spiking 9 × 1-inch boards across the sides of the rakers and at right angles to the wall piece. The feet of the rakers are bound together with hoop-iron banding secured by clout nails.

Flying Shores.—The flying shore is a composite strut fixed in a horizontal position, and designed to hold apart buildings tending to collapse, and may be used either across a narrow street or on a site from which a building has been removed, leaving two buildings on the plots on either hand without the support previously afforded by the building now removed.

The main advantage to be gained by the use of this type of composite shore is that it affords the required support and at the same time leaves the street or the site unencumbered.

Where this type of shore is used to support two buildings as described during building operations on the site between them, it is generally found advisable to support the ends of the front walls by means of raking shores, in addition to the horizontal or flying shores. The distance apart of the

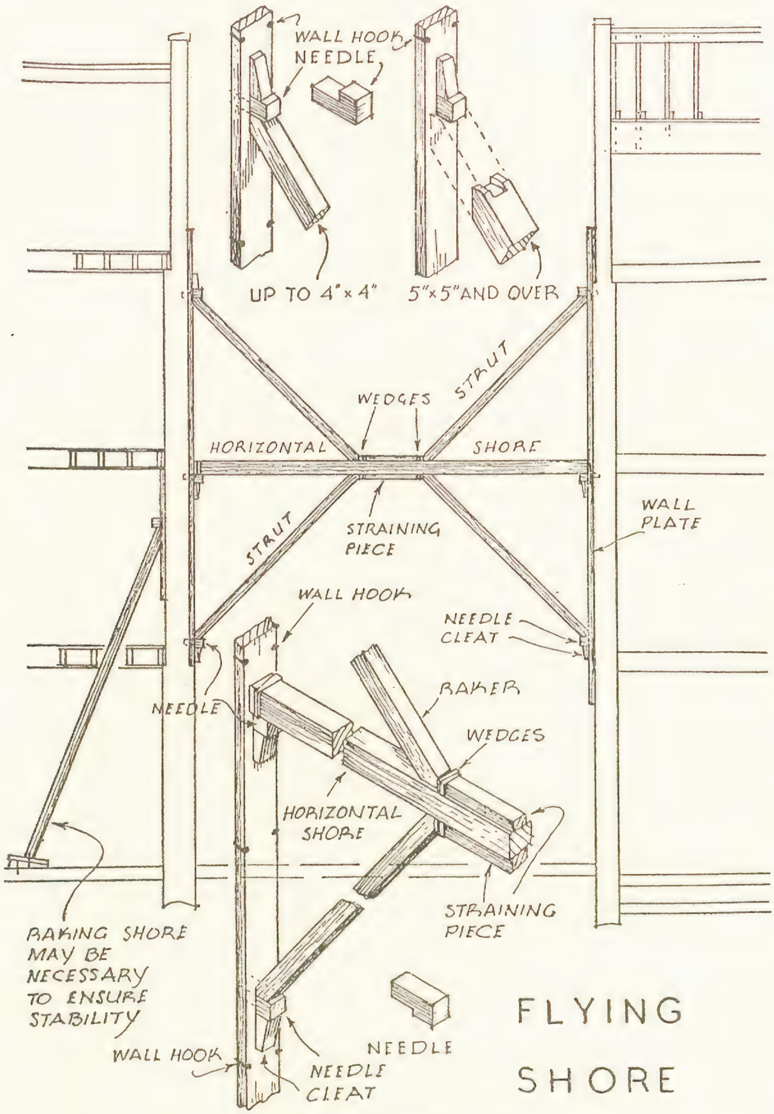


Fig. 61.—Flying shore.

two buildings must not be greater than 40 feet if an ordinary flying shore is used. Where the distance is greater, a truss of queen-post type must be designed of sufficient strength to be rigid in its stiffness. In such positions as where the trusses are used parallel to each other, a cross truss or shore is sometimes required, run at right angles to the flying shores, and parallel with the walls and at a point half-way between them.

The principle underlying the design of the flying shore is the triangle, and the points of resistance of the various parts of the shore are, as with the raking shore, those at which the rafters and joists rest on the walls. In considering a flying shore, constructed to support a building for three storeys of its height, the position of the central member—a 9 × 9-inch baulk run horizontally—is arrived at by fixing it in such a position that its centre line is a continuation of the centre line of the floor joists.

From this centre horizontal strut, there are run, both upwards and downwards, struts at an angle of 45° with the horizontal member. For the struts on the upper side of the horizontal member the points of contact of the upper ends are found by producing their centre lines till they cut the centre line of the wall plate under the floor joists. The

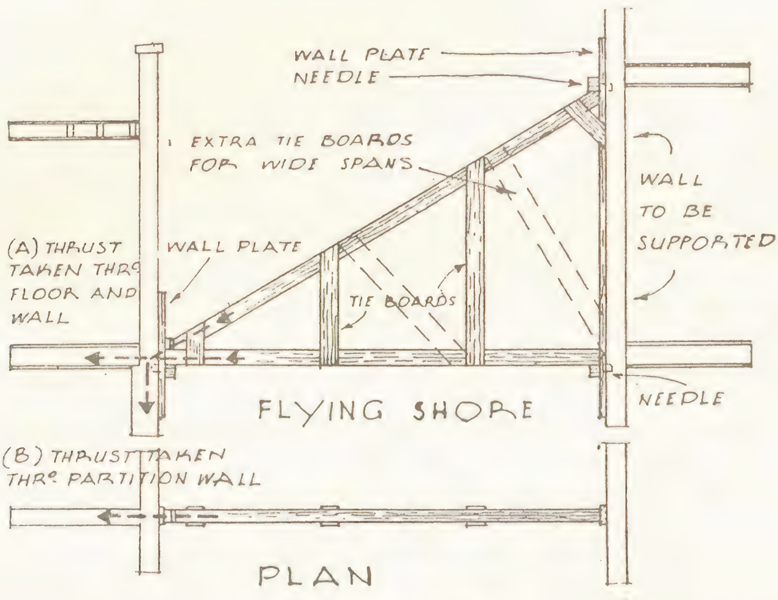


Fig. 62.—Triangular flying shore.

correct point of contact of the struts on the underside of the horizontal shore should be found by producing its centre line until it cuts the centre line of the floor joists in the centre of the wall.

Wall pieces, needles and cleats are fixed in the same manner as for raking shores.

The Method of Erection of a Flying Shore is first to fix in the correct position the wall pieces as described with the needles inserted and the cleats fixed. Next straining sills of the required length to give the proper distance to obtain the angles for the struts as obtained from the drawing already described. These straining sills are fixed on both upper and lower sides of the horizontal member.

The struts on the underside of the horizontal are then fixed in position, wedges being driven in at their lower end between their feet and the wall

piece. In driving these wedges care must be exercised to see that too great a strain is not created, as the purpose of the shore is to resist possible pressure of the walls and not to exert pressure on the walls. The struts above the horizontal may then be fixed, having the wedge in their case between their feet and the ends of the straining sill. The tops of the upper struts and the bottoms of the lower struts, besides being splay cut to the required angles, are notched and shouldered to fit round the needles in a similar manner to that described for the raking shores. There must also be needles and cleats under the horizontal shore; and all junctions of the various timbers should be dogged.

Sizes of Flying Shores.—

Horizontal shore up to 20 feet long	6 inches × 6 inches
Horizontal shore up to 25 feet long	7 inches × 7 inches
Horizontal shore up to 30 feet long	8 inches × 8 inches

Struts 4 × 4 inches, or 6 × 6 inches, according to length.
Wall plates 9 × 2 inches or 3 inches.
Straining pieces nailed to the horizontal shore are usually 4 × 2 inches.
Oak needles 4 × 3 inches or 4 inches.

It will be seen in Fig. 61 that a 4 × 4-inch strut is merely butted against the needle, though iron dogs should secure the ends; but if the strut is 5 × 5 inches or over, the end of the strut should be notched against the needle, as with raking shores.

Dead or Vertical Shores.—These shores are used, generally in conjunction with raking shores, to give support to a wall, the foundations of which are sinking or in which it is required to cut a large opening for such purpose as, say, to insert a large bay or a shop window. As the name suggests, they afford support in a vertical direction; and it will be obvious that the strength of the timbers must be equal to the strength of the material which is removed. The timbers must also be disposed in such a way that they cause as little interference as possible with the operations required.

In supporting a building for such purposes by means of dead shores, it is necessary first to undertake certain supplementary shoring and strutting. Where the building is at all dilapidated, all the door and window openings must be strutted squarely to resist any deformation. Where the windows are arched, turning pieces and centres must be strutted in tightly against the arch, and the reveals of all openings must be fitted with uprights between which straining struts are driven at an angle to induce considerable pressure. In this instance, and contrary to the wedging of the struts to flying shores, actual pressure is required, as the forces of distortion will not be experienced until the lower portions of the structure are cut away, when it will be too late to introduce resistance satisfactorily.

The next necessary preliminary operation is to strut the floors inside the building with struts of sufficient strength to relieve the front wall of

any of their weight. This strutting will require to be formed of timbers of 4 × 4 inches, 6 × 6 inches, or greater according to length, load and spacing, and it is essential that the support they afford should be continuous throughout the height of the building, and be based on a solid foundation, such as is afforded by a concrete floor to a basement. If the lowest floor is of wooden construction, it must be taken up, and a solid foundation either found or formed below for the lowest strut to rest upon. Under the feet of the uprights, sole pieces 9 × 2 inches must be inserted, and across the heads for the total width of the floor head pieces, 9 × 2 inches, must also be run. To tighten these supports wedges may also be used; in this instance the wedges must not be driven to exert a strain, but only a stiffening of the resistance.

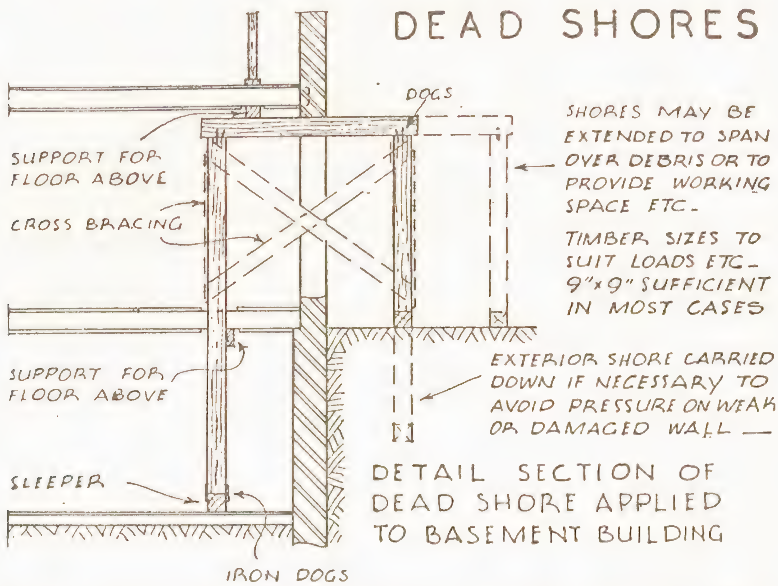


Fig. 63.—Cross section, showing dead shoring to wall in a basement building.

Raking shores may next be fixed against the wall, though for most ordinary operations, such as those suggested, these will not require to be more than single shores.

When these supports have been firmly fixed, holes may be cut in the wall at points above the required opening, and not more than 6 feet apart, horizontally. Through these needles of timber 12 × 12-inch or steel joists of equivalent strength are then inserted. Support is given to the ends of these needles by baulks 13 × 13 inches, which are the actual dead shores. These should rest on sleepers 13 × 13 inches, and where there is a basement, must be continuous to the basement floor or other solid foundation. Care must be taken to see that there are no voids or vaults under the bases of the dead shores.

The dead shores and needles may then be wedged up and the whole left for a day or two to settle.

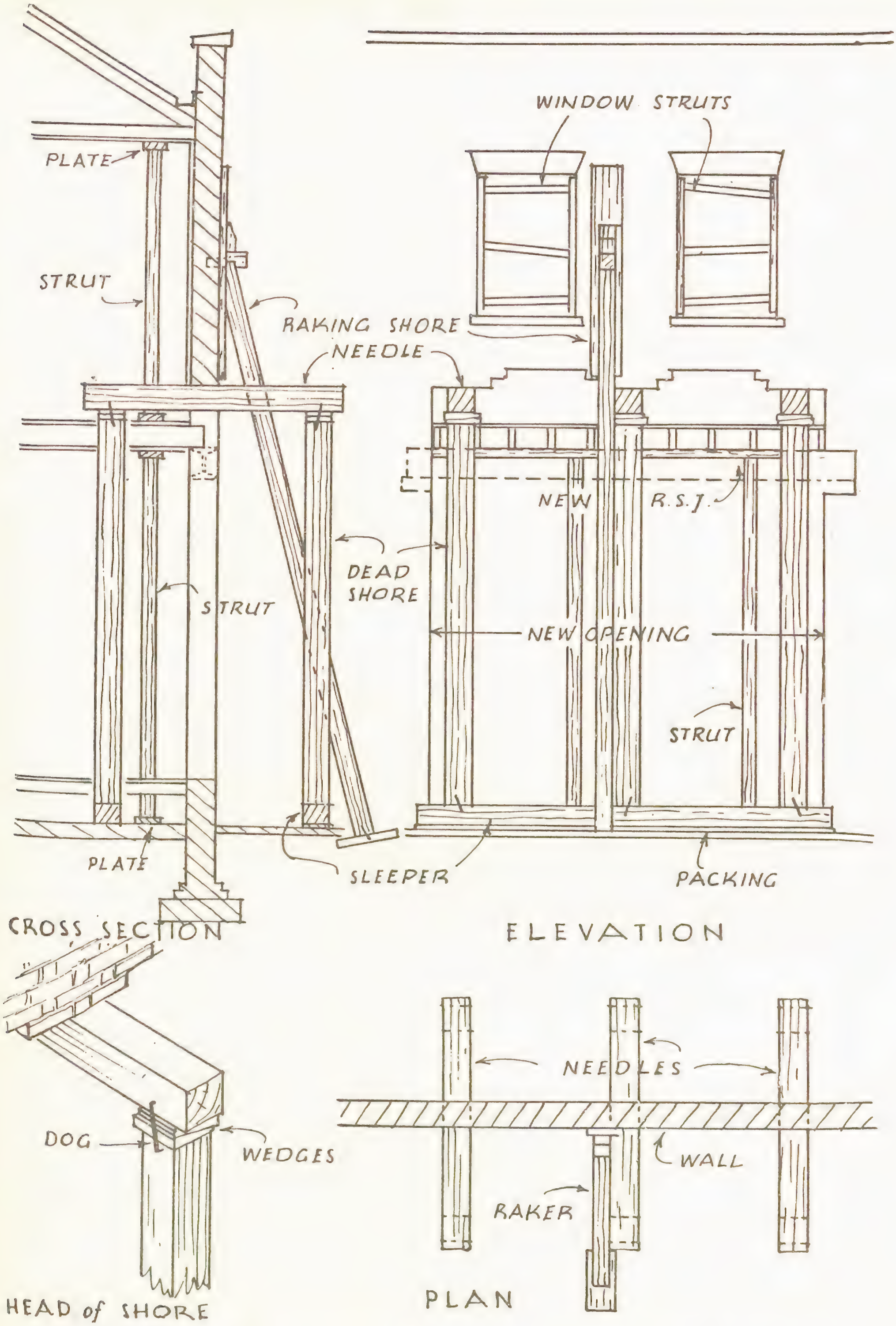


Fig. 64.—Shoring for the provision of a wide opening (for a shop window, gateway, etc.).

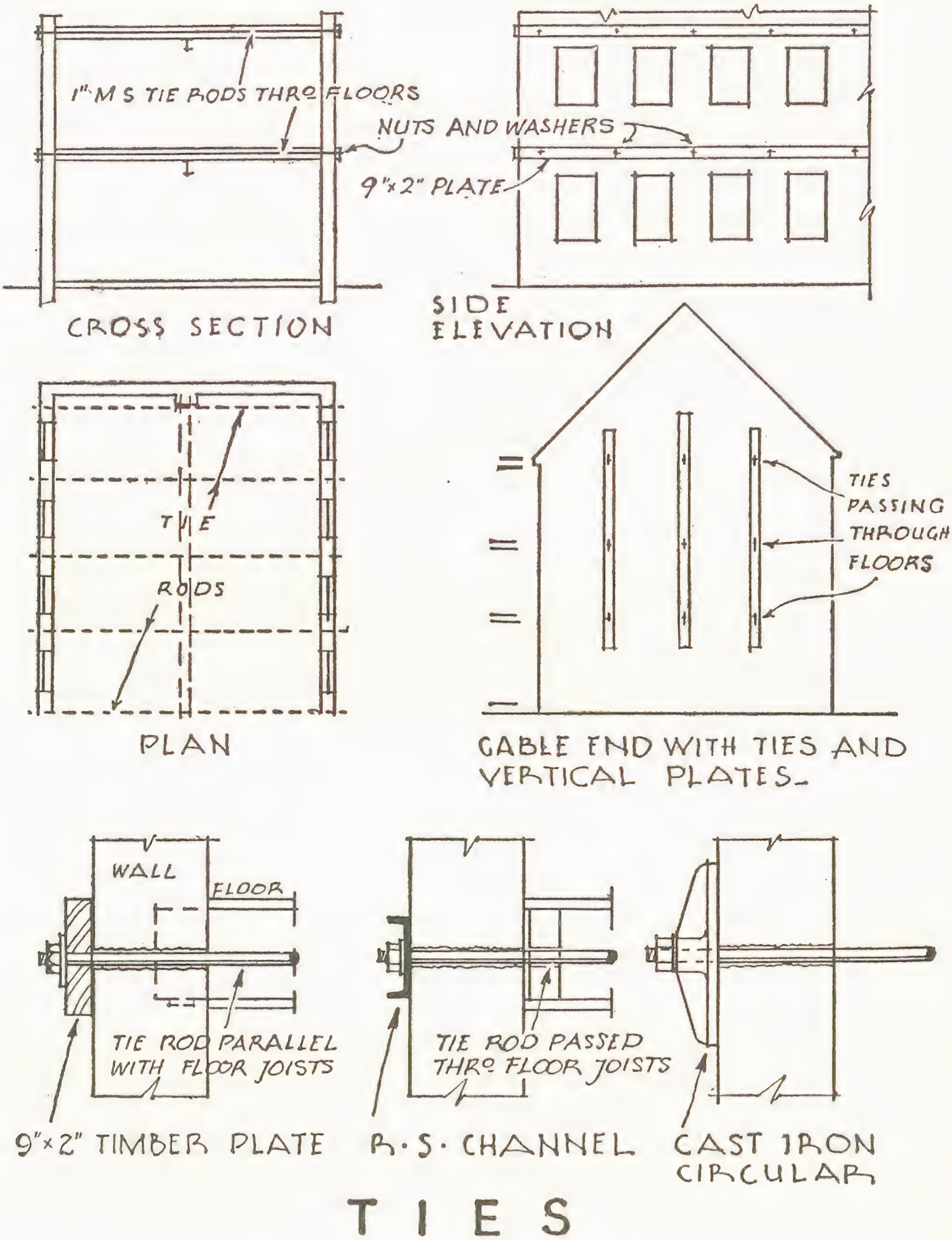


Fig. 65.—Strengthening walls by steel tie rods.

Sizes of Dead Shores.—Dead shores and needles vary from 9 × 9 inches to 13 × 13 inches. As the safety of the structure depends on adequate strength a substantial factor of safety should be allowed. For heavy loads or with a structure in a dangerous condition calculations should be made for the timbers.

For such work as making an opening in an existing house wall for a shop front or bay window, 9 × 9-inch timbers are adequate.

Steel joists are often used for the needles. With suitable connections steel joists can also be used for the dead shores.

UNDERPINNING

After the shoring operations last described have been undertaken, it will generally be found necessary to underpin the wall that has been thus temporarily supported.

Underpinning may consist of just the single pier to support a portion of the foundations that have sunk, or the whole length of a party wall may require a new wall building underneath it, to support the entire party wall, and to form an enclosure for a new cellar that is to be excavated.

The first case will present no difficulties, requiring only an excavation alongside that portion requiring support to a depth sufficient to afford a good foundation for the pier to be built up underneath the foundations of the existing wall.

Where, however, the whole length of the foundations of a party wall has to be underpinned, it is obvious that this cannot be excavated for in one continuous operation. The method actually employed becomes really a series of underpinnings in sections of from 3 feet to 4 feet long. The work is carried on to the various sections in alternation. For example: the wall is marked out in the 3-foot section and numbered as follows: 2, 7, 4, 9, 5, 10, 6, 3, 8, 1, these figures representing the order of procedure. The brickwork is built upon a solid foundation having concrete base and footings of the ordinary design, and the earth is then returned behind the new wall and well rammed as its construction proceeds. The foot-

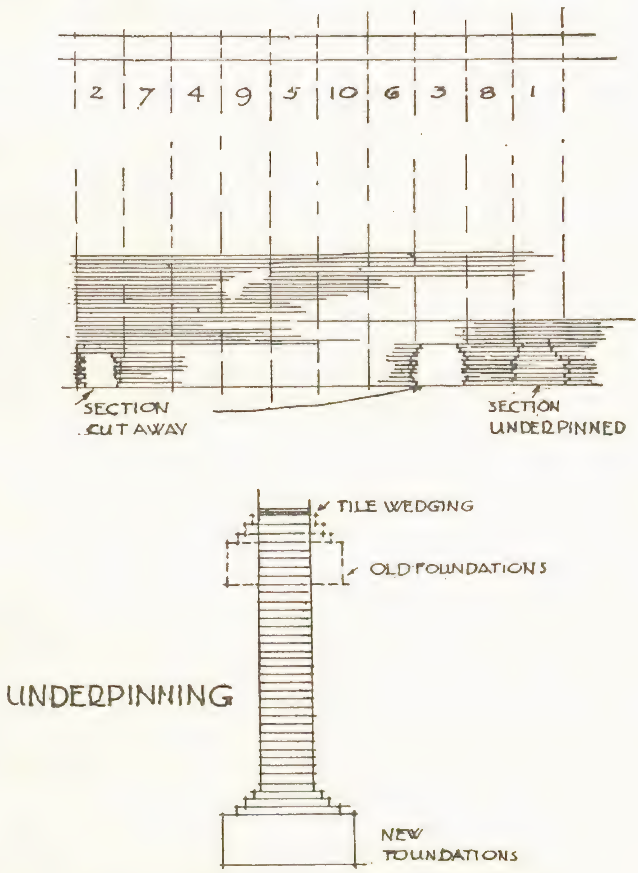


Fig. 66.—Underpinning elevation and section.

ings and concrete to the old wall, on the side of the new cellar or excavation, must be cut away to give a flush face with the new and old walls. When the brickwork of the new underpinning wall has reached almost to the underside of the old concrete, the space left will not be sufficient for a full course of brickwork. This, however, may be filled in with slate tightly wedged and set in cement. The centre line of the thickness of the new wall should come vertically under the centre line of the thickness of the old wall.

Time must be allowed for the alternative sections to settle before the work to the remaining sections is put in hand, and if the soil is of a loose nature the excavations may require to be supported by timbering, as is to be described later. But in no case should any timbering be left in at the completion of the work.

In order to facilitate the exactness of operations, the first step necessary is to mark on some permanent portion of the building a datum line, and all measurements downwards should be measured from this. This will save considerable time in the matter of bonding section to section and in keeping the brick courses horizontal.

For new cellars there should be a vertical dampcourse run over the face of the new underpinning wall, and that of the wall underpinned, which may be covered up by a half-brick wall known as the Retention Wall.

Where the underpinning is to form an external wall for a new basement, the half-brick retention wall will be formed on the outside instead of the inside, and the old footings and foundations to the existing wall will be entirely removed, the brickwork of the new wall being pinned and wedged up to the last course of the existing wall before the offsets.

Underpinning for New Bay or Shop Window.—After the Dead Shoring already described has been fixed, and the brickwork of the wall thus supported, the girder or wooden bressummer is supported either on new piers of brickwork or steel stanchions of the requisite dimensions. Brickwork and a pinned and wedged course is then built over the new bressummer, or alternatively a relieving arch may be turned. (See Fig. 64.)

Concrete Underpinning.—If it is desired, underpinning may be executed in concrete, but in this case it will be necessary to allow at least three weeks before the shoring is removed, unless rapid-hardening cement is used, and though the timbering behind a concrete wall underpinning a party wall must of necessity be left in, no cross struts running through the concrete wall should be allowed to remain. As this precaution causes considerable additional trouble, it is often overlooked, and is the cause of difficulties when the wood rots.

HOARDINGS

Before any other work is started, including even pulling down an existing building, a hoarding must be erected along the entire length of the frontage. The type and dimensions of this structure will depend upon the extent to which use is to be made of it in the forthcoming operations. If it is merely in the nature of a fence to keep the public out, it will not need to consist of anything more substantial than a close-boarded fence fitted together in sections with a pair of doors to give access to the site. But if it is to be used as a staging for the hoisting and to an extent the stacking of building material, a much stouter structure will be called for.

Light Hoardings are formed of close boarding nailed to 4 × 2-inch rails and 4 × 4-inch angle posts. A more decorative effect is given to the hoarding externally if V-jointed boarding is used, a sheeting having a chamfered capping 6 × 2 inches run along the top and a 6 × 1-inch vertical fascia covering the corner posts. The 6 × 1-inch fascia may be introduced at distances in the length of the hoarding to form panels in the sheeting.

The hoarding may either rest on the ground, or if a more substantial fixing is required, a 12 × 6-inch baulk should be first laid along the frontage and the hoarding be erected on that. In either event the hoarding must be strutted and shored from within in a permanent and durable manner.

Heavier Hoardings, where they are in the nature of elevated platforms for materials, and contain a temporary footway for use of the public during operations, are constructed as follows. They consist of two frameworks of squared timbers having sills of 12 × 9 inches or 12 × 12 inches, uprights 9 × 9 inches, heads 9 × 9 inches, with joists 2 × 10 inches run across from frame to frame, and 9 × 3-inch planks as flooring over the joists. The method of construction is first to lay the sleepers on the ground, and then to raise on them in the required position the uprights, dogging them to the sill. The heads are then placed across the tops of the uprights and dogged in a similar manner. Struts 4 × 4 inches are then cut in diagonally as angle stiffeners between the uprights, and tightened up with wedges driven between at their bottom ends and cleats fixed for that purpose.

Where a footway for the public is required, 2 × 6-inch joists are cut in over the sleepers or sills and 9 × 2-inch planks run along these. A handrail at a height of 3 feet above the footway is cut in between the uprights. A fender 12 × 12 inches is also fixed on the outside of the uprights. This should be cut splayed at all openings and at its end.

Entrances to hoardings, whether movable or hinged, should be supplied with a letter-box, and the name of the contractor should appear above this.

Regulations.—It is provided in the regulations concerning scaffolding in the City of London—and the points are all worthy of note for guidance in the erection of scaffoldings elsewhere—that :

" No hoarding or scaffolding is to project beyond the footway pavement where it is narrow, nor more than 6 feet where it is wide enough to admit of such projection ; any deviation on account of special reasons to be stated upon the licence.

" No hoarding is to have doors opening outwards. Hoardings and scaffoldings are to be watched and lighted at night. Where practicable or needed, a boarded platform 4 feet wide, and as much wider as may be necessary for the traffic, with stout post and rail and wheel kerb on the outside of it, are to be constructed as the Inspector may direct.

" No hoarding is to be enclosed so as to prevent passengers passing under it. The lower stages are to be close or double planked, each stage to have fan and edge boards, and such other precautions as the Inspector of Pavement requires to prevent dust or wet falling upon the public, or for the public safety. No materials are to be deposited below any scaffolding. If, in the opinion of the Inspector, it is necessary for the public safety, a hoard licence to be granted instead of a scaffold licence."

OFFICES—FOREMAN AND CLERK OF WORKS

Offices for the use of the foreman, and the clerk of works where there is one, will be required to be provided by the contractor, and a mess-room for the men should also be erected. This latter should be of a sufficiently permanent nature and in such a position that it need not be removed until the building is completed, as the practice of allowing the use of one of the rooms of the new building for this purpose is not a good one. Storage sheds for cement are required, and sites for stacking timber must also be provided, and wherever possible, shops for the painter and the plumber are preferable to the more usual custom of using half-finished rooms in the building.

Most specifications also call for the provision of latrines for the use of the workmen. These must be frequently cleaned out and the contents deposited where it will not cause inconvenience or disease. Dry rot and other fungi may be originated by the improper use of the building in this respect.

The most suitable offices for the use of foreman and clerk of works are light huts of the ready-made type, built in sections to be bolted together. Each should be provided with a flat-topped table along the side in which the window is situated, fixed at a height of 3 feet 6 inches from the floor for use as a drawing-table to support drawing-board and plans. The door should be fitted with a lock and a letter-box. Heating stoves should also be provided.

An important point in the choice of position for these offices is that they should, wherever possible, be so situated that supervision of and

access to all parts of the work are convenient. It is also advisable that they should not be at too great a distance from the entrance to the site.

LARGE FITTINGS

Any large fittings such as boilers, engines, or other accessories of such a nature as to be regarded as one-piece fixtures of too large dimensions to be introduced into the building after the doorways and floors are constructed, must be brought into the site and housed suitably under temporary coverings before the building work is proceeded with.

Hoists and gantries, engines, etc., for use in raising heavy steelwork should also be placed on the site before the structure is commenced.

CHAPTER 6

EXCAVATING

PRELIMINARY OPERATIONS

The preliminary operations necessary on a town site will be obviously very different from those for a site in the country. The difficulties which have to be overcome as to cartage and distribution of the excavated soil on a town site are often great, whereas on a country site it is generally nothing more than a matter of depositing the excavated soil where required by the building owner. For this last, carting will rarely be required, barrowing being sufficient. To facilitate this, plank runs should be laid from the excavations to the point of deposit. Considerable time will be saved in this matter by having two runs, one for going and one for returning, instead of, as is so often seen, a single run for both-way traffic.

For excavations of an ordinary depth, on a country site, little if anything in the way of hoists will be required, but for deep trenches, such as are sometimes necessitated for either basement foundations or drainage trenches, some extra timbering and platforming work will be necessary to facilitate the throwing up of excavation. The construction of these will be found under the heading Timbering Trenches on page 101.

EXCAVATION ON A TOWN SITE

Where a new basement has to be excavated for on a town site, the soil will require removing altogether. For this purpose it will be a great help if the carts employed can be filled at the actual point of excavation, and an inclined runway, leading downwards from the entrance, will save time and labour. In the majority of cases this may be constructed of sleepers laid across the cartage way, held in position by baulks run along their ends to prevent the sleepers getting out of position and at the same time to keep the cart wheels in the track.

EXCAVATION BY MACHINERY

On town sites where large cellars are to be excavated, considerable time and labour is saved by the use of machinery, for the actual operation of excavation as well as hoisting. By means of an excavator combined with a crane, the excavated soil can be loaded straight into the carts and disposed of. If these operations are extensive the general contractor will be well advised to sublet them to specialists who have the

machinery, but should he wish to carry out the work himself, and at the same time not possess the machinery, this can be hired from merchants who specialise therein.

EXCAVATING DATA

Slopes.—The following data give the angle with the horizontal line at which the different kinds of soil may be sloped naturally:

WITH HORIZONTAL LINE

	Degrees.		Degrees.
Compact earth	50	Dry sand	38
Clay, well drained	45	Vegetable earth	28
Rubble	45	Wet sand	22
Gravel, average	40	Wet clay	16
Shingle	39		

Weight of Earth.—For aid in calculating costs of excavating, the following table of weights of earth will be found helpful:

PER CUBIC YARD

		Cwts.			Cwts.
Slate	about	43	Chalk	about	36
Trap	,,	42	Clay	,,	31
Granite	,,	42	Gravel	,,	30
Quartz	,,	41	Sand	,,	30
Shale	,,	40	Marl	,,	26
Sandstone	,,	39	Mud	,,	25

Labour.—In excavating it is generally reckoned that a man can throw in loose ground 10 cubic yards a day, and in hard or gravelly soil about 5 cubic yards per day. For purposes of calculation, it may be reckoned that three men will remove 30 cubic yards a distance of 20 yards per day.

Barrowing and Carting Data.—

A dobbin cart holds about $\frac{3}{4}$ cubic yard.
A wheelbarrow holds about $\frac{1}{10}$ cubic yard.
An earth wagon holds $1\frac{1}{2}$ cubic yards.
A large earth wagon holds 3 cubic yards.
20 yards equals one run.
27 cubic feet equals 1 load; equals 21 striked bushels.
54 cubic feet equals 1 double load.

Increasing Bulk.—In calculating excavations it should be remembered that soil when dug occupies a greater cubic space than before digging, and the following table gives the increase in bulk in different soils:

	Before digging.	When dug.
Earth and clay	1	$1\frac{1}{4}$
Sand and gravel	1	$1\frac{1}{10}$
Chalk	1	$1\frac{1}{3}$

Dimensions per Ton.—The following table gives the cubic dimensions in feet per ton of various soils:

Sand, river	21	Marl	28
Sand, pit	22	Clay	28
Thames ballast	22	Chalk, lump	29
Gravel, coarse	23	Night soil	32
Shingle, clean	24	Earth mould	33

Note.—The further list of the weights of different kinds of soil will be found helpful in excavation operations.

Name of Earth	Weight.	
	Decimals of a ton. Cubic feet.	Tons. Cubic yards.
Basalt, solid	0·083	2·25
Bath stone, solid	0·052	1·40
Chalk, damp to wet, loose to close	0·056–0·074	1·50–2·00
Clay	0·054–0·059	1·45–1·60
Flint, solid	0·074	2·00
Granite	0·078	2·10
Gravel and shingle	0·046–0·055	1·25–1·50
Limestone lias to Compact mountain	0·067–0·078	1·81–2·10
Marl	0·044–0·052	1·20–1·40
Mud at surface	0·044	1·20
Mud at about 15 feet in depth	0·048	1·30
Peat, hard and top mould	0·036	0·98
Portland stone, solid	0·065	1·75
Quartz, solid	0·076	2·05
Sand, dry river	0·041	1·10
Sand, damp and shaken	0·055	1·50
Sandstone, solid	0·063–0·072	1·70–1·95
Shale	0·074	2·00
Slate, solid	0·08	2·15
Trap, solid	0·078	2·10

LEVELLING THE SITE

It may be that a sloping site in the country requires levelling before the excavations for the trenches are dug.

On a large site the surveyor's level and staff can be used to fix the levels of pegs as a guide to the workmen.

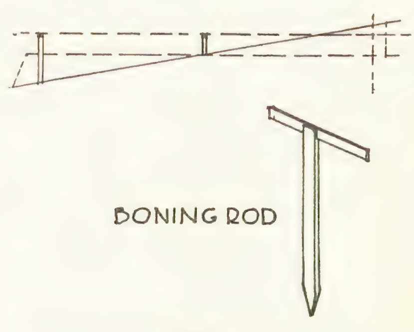


Fig. 67.

Where it is a matter of shifting the soil from a higher to a lower part of the site a boning rod is driven in at the half-way line where the excavation will finish and the filling in begin. The height of this boning rod above the ground is taken. This will require to be greater than the depth of the greatest amount to be excavated. Another boning rod is then driven in at the lowest part of the site, its

top being level with the rod at the centre of the site. It may be necessary to drive several intermediate rods, as the levels will be obtained by means of the spirit level and straightedge.

Excavations may then be commenced to a depth to be ascertained by sighting a line over the tops of the boning rods, and when this level has been reached and the soil from the excavation wheeled and rammed on the lower portion of the site, a level surface should have been obtained throughout the whole site, and this surface will be a distance below the level of the boning rods equal to that of the height of the original boning rod from the ground. It will be obvious that many sites will slope in more than one direction, and then it will be necessary to fix boning rods showing the level to be obtained at right angles to the first line also.

Boning rods consist of a post and cross rail which is known as the *Sight Rail*, fixed at right angles to the upright post. The foot of the upright post is pointed to facilitate driving into the soil. These sight rails must be distinguished from those in use over trenches. These consist of short pointed stakes with cross rails fixed to them and driven into the ground on either side of the trench to be dug, the sight rail extending across the trench. On these sight rails above or below the datum, already referred to, is marked the centre line of the wall, the spread of the footings and concrete foundations, and the width of the trench to be dug is also marked, and later, when brickwork is commenced, the bricklayer's line is stretched from sight rail to sight rail, and the face of the brickwork determined by a plumb bob let down from the bricklayer's line.

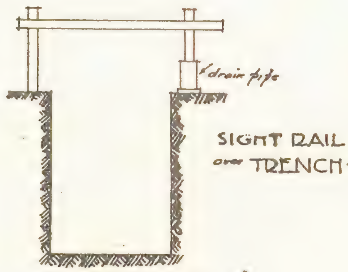


Fig. 68.

Levelling Trenches.—Boning rods may also be used for levelling the bottoms of trenches for foundations, and again the height of the boning rods must be referred to the datum level fixed in a permanent position on the site.

Stepped Trench Bottoms.—On very sloping sites considerable money may be saved in foundations by stepping the trench bottom in short or long steps in accordance with the angle of the slope. The timbering required for these step trenches will be of necessity different from that for ordinary level trenches, and will be found described later.

Note.—A very important matter which should be carefully noted is that before any other steps are taken to set out a building, it is essential that the building line should be ascertained from the local authority, and that this line should be set out by the local authority's surveyor or by the builder. In any case, it should be checked and approved by the surveyor, the builder, architect, or clerk of works, and clearly marked by pegs or other means.

PEGGING OUT

Before the trenches for the foundations are excavated the lines of the trenches must be pegged out. The levels of the site having been taken as described in Chapter 2, it is essential that the datum line be marked upon some fixture which will remain during the whole of the building operation, as all dimensions will require to be referred back to this datum.

Boards are fixed to upright pegs at a distance of 3 feet from the trench line. These profile boards consist of 1×7-inch planks on edge. The pegs are out of 4×3-inch stuff driven well into the ground, but as certain permanent dimensions are to be marked on these profile boards, the soil if loose must be replaced by concrete around the pegs.

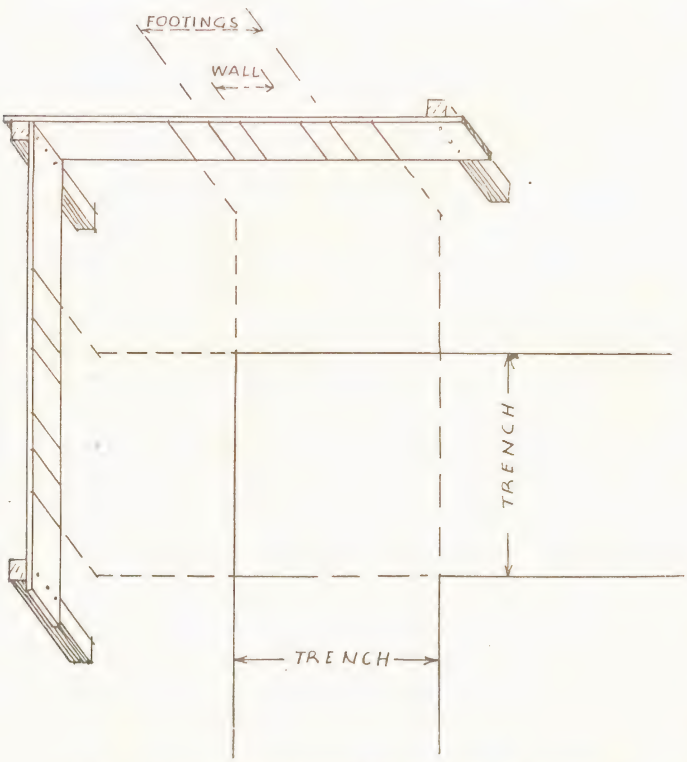


Fig. 69.—Foundation profile boards set up at corner.

On the profile board are marked the centre line of the walls to be built, their thickness, and the extension of the footing and concrete on either side of the centre line. The marks should be made with saw cuts painted in red.

Where the frontage line of the building is broken up with projections and angles, it will be found very helpful if the profile boards are continued round the whole building. The exact position of each break can then be marked on accurately. The outline of the outer walls being thus pegged out over the whole site, diagonal cross dimensions should be taken from corner to corner of the building and checked with the cross dimensions on the plan. This will provide a check on the correctness of the external dimensions and the rectitude of the angles. Any projections or bay windows, buttresses and chimneys, are then laid out on wooden templates, and transferred to the line of the building, in position, and when required. The measurements are best set out on the

site by the aid of a metal tape, though wooden rods are often employed, and though the metal tape has no tendency to stretch, an inch or two may be lost by its tendency to sag if held at a height from the ground.

Wooden squares having long arms framed together at 90° are used for setting out corners and return walls within the building.

Right-angled corners may be set out with the tape by the 3 : 4 : 5 rule described in Chapter 3, page 51.

TIMBERING EXCAVATIONS AND TRENCHES

Where excavations are deep or the soil loose, especially on town sites where new basements are to be excavated for, the sides of the excavations will be required to be supported with timbering of an unusual nature. For it is obvious that in an excavation for a cellar, it will be necessary to strut the timbering at an angle; and as the earth on which these struts at an angle rest has later to be removed, the work will require to be done in stages.

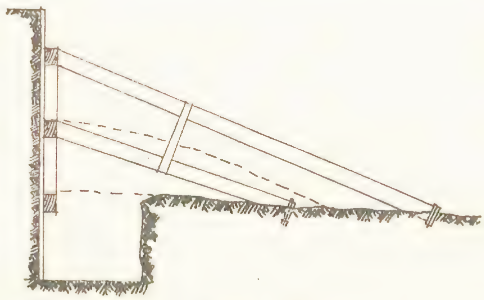


Fig. 70.—Cellar excavation.

In such cases it is customary to excavate a first section about 3 feet deep, sloping downwards towards the centre of the site. The top row of timbering is then fixed against the vertical face of the excavation and supported by the inclined shore mentioned, these shores leading to the deepest excavated portion of the site at the centre. The sloping earth is then excavated, and the next system of timbering is fixed in position against the vertical excavated face and shored with inclined shores vertically under the first system. The trench for the wall is next excavated for and timbered on both sides as described for ordinary trenches.

Wide Excavations.—The ordinary timbering to be described for trenches of average width will not be adequate for wide excavations or for deep shafts. For wide excavations there will require to be guide piles fixed intermediately at intervals, and intermediate upright supports to the cross struts. These are required to afford stiffening to a system which would otherwise fail on account of the weight of the cross timbers.

Shafts.—For lift wells and deep foundations under steelwork, it is often found necessary to sink shafts from 4 feet square and upwards. The sides of these shafts require to be sheeted in a peculiar manner which will also be found described later. The excavation to shafts proceeds stage by stage, the timbering following as each stage is finished, and the timbering, if the depth is great, requires to be supported to prevent it from sliding down as the earth below is removed.

Definitions.—Before proceeding further with the description of the timbering required in different circumstances, it will be helpful to give the names and purposes of the various members used therein.

Sheeting.—Close boarding from $7 \times 1\frac{1}{2}$ inches to 9×2 inches placed against the vertical face of the earth excavated, either horizontally or vertically, is termed sheeting, and is necessary where the soil is loose or the excavation deep.

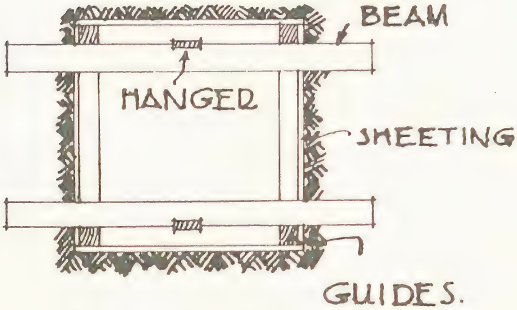


Fig. 71.—Timbering for a shaft—Plan.

The principle underlying the timbering of trenches is quite simple, in that it consists in giving support to vertical faces of soil exposed as the result of excavation. Earth is taken out, and consequently some form of support is required to supply the pressure originally exerted to hold the earth exposed in position.

Timbering in its simplest form consists of an upright placed against the face of the excavations on both sides, held apart by a strut. The upright timber is termed a *Poling Board*, and is usually in stock of the dimensions of 3 feet $\times$ 9 inches $\times$ $1\frac{1}{2}$ inches. The *Strut* is generally a short length of scaffold pole about 4 inches in circumference, or it may be of squared timber of 4×4 inches. These dimensions are for ordinary excavations of average width. For wider excavations the strut, though serving the same purpose, will naturally require to be of larger dimensions.

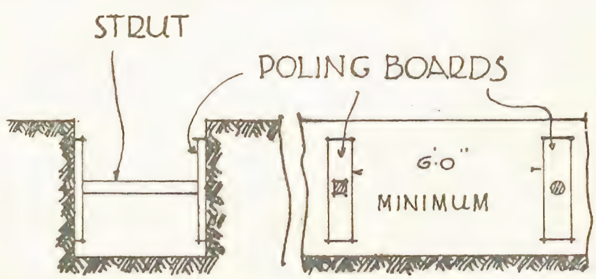


Fig. 72.—A shallow trench in firm soil.

The timbering last mentioned will be all that is required for ordinary trenches about 3 feet deep and 4 feet wide, in ordinary firm ground. But where the ground is what may be termed moderately firm, a trench of the same dimensions will require slightly additional support. Whereas, in firm ground, the minimum distance between the poling boards is 6 feet, in moderately firm ground, if the same system were carried out, it would require that more frequent horizontal support should be given. To employ the same system in giving this more frequent support would be unnecessarily expensive, in that there would be a wastage of time and material in fixing the additional struts. To serve the same end, the same number of struts may be used in conjunction with a horizontal piece of timber stretching along the length of the trench and pressing an additional number of

poling boards. This horizontal timber is called a *Waling Piece*, and is generally out of 6 × 4-inch timber. The method of construction in timbering in these circumstances is to place the poling boards against the vertical face of the trench, at distances of from 12 inches to 9 inches apart, and then to lay the waling piece horizontally along the trench at their centres, and to exert pressure upon them to hold them in position, by driving in the circular or square struts cut slightly longer than the width between the waling pieces at distances of not less than 6 feet apart. The object in having the struts slightly longer than the horizontal distance between the waling pieces on either side of the excavation is that, in being driven into position by blows with the mallet, they exert a pressure on the waling pieces which by way of every poling board is communicated to the side of the excavation.

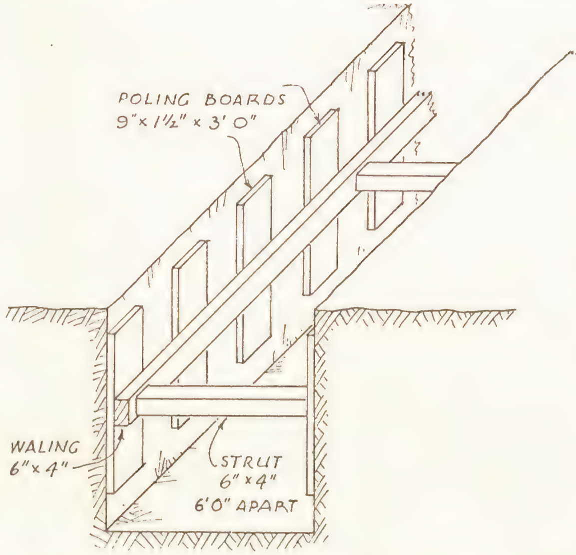


Fig. 73.—Poling boards and struts in shallow trench in moderately firm ground.

Continuous Sheeting.—Where the earth is loose or waterlogged, sheeting will be required that is continuous and close jointed. To hold this in position against the earth, struts and poling boards are employed in the same manner as for the trenches already described. The dimensions of the sheeting are 9 × 1½ inches, and in length generally about 13 feet; the poling boards are 9 × 1½ inches in 3-foot lengths, and the struts 4 inches circular, two to each poling board, one at the top and the other at the bottom. In laying in the sheeting, it is customary first to strut a single board along the bottom of the first excavated portion of the trench, and over and resting on this, the system as described, held in position by poling boards and struts, is then erected. Should the trench require to be deeper than the first excavation, the bottom temporarily strutted board is removed, and a second system of sheeting, etc., is strutted across the second excavation.

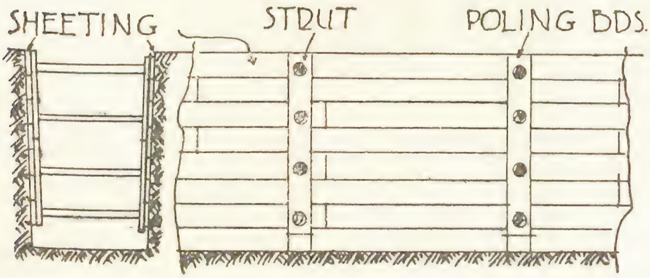


Fig. 74.—Horizontal sheeting.

In waterlogged soil, running sand, etc., the method last described is used, but the sides of the trench are cut sloping inwards from the top.

Wide Excavations.—As has been already pointed out, wide and deep excavations require timbering of a reinforced nature. For this purpose strong piles, shod with iron, driven to a depth of a foot below the required depth of the trench, serve as stiffeners to hold the sheeting in position. The sheeting then becomes known as *Sheet Piles* or *Runners*. These piles are 9 × 3-inch boards having the bottoms cut off diagonally and given points known as chisel points. For hard soils the feet of the sheet piling are shod with metal shoes. The guide piles and sheet piles having been driven into position—the minimum distance between the guide piles is 7 feet 6 inches—the earth is then excavated. And as the excavation proceeds the sheeting is strutted apart from side to side of the excavation by 9 × 9-inch struts, strained against 9 × 9-inch waling pieces. The weight of these timbers requires additional support, and this is afforded by cleats being nailed to the guide pile under the waling pieces at the point where the struts rest against them. Where still further additional support is required, raking shores are fixed as the excavation proceeds, having their upper ends butted against the chamfered end of the cleat.

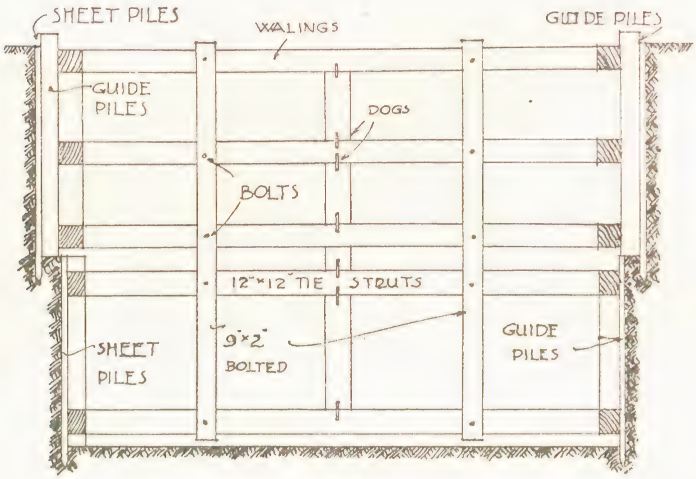


Fig. 75.—Timbering for wide excavations.

Where the sheet piling is not sufficiently long, being in 12-inch lengths, to reach to the bottom of the required excavation, another series of sheet piles is required, and these are driven in within the first in exactly the same manner when the first excavation reaches a depth of a foot or so of the bottom of the first sheet piles. This operation may be repeated as often as may be required to reach the necessary depth. But it should be remembered that the width of the excavation is narrowed by 2 feet at each stage, and this should be allowed for in setting out the width of the first excavation. If additional stiffness should be required to support the 9 × 9-inch struts in their length, this can be afforded by driving in 6 × 6-inch uprights from one strut to another.

Whereas these methods detailed give the standard types of timbering customarily met with in ordinary operations, it will be clear that special

conditions require special treatment, and that so long as the principles detailed are borne in mind, the contractor will require to use his own discretion.

Deep Excavations for Drains.—Trenches for drains in certain positions and on certain sites may require to be excavated to a considerable depth, but at the same time will not require to be wide, and in the construction of these the problem of throwing up the soil will need special consideration in the matter of the disposition of the timbering. A man cannot throw from the bottom of a deep trench; consequently platforms require to be arranged diagonally at distances not more than 4 feet apart in height. The topmost platform should be a less distance than this in order that the throw may carry the earth well away from the top of the excavation.

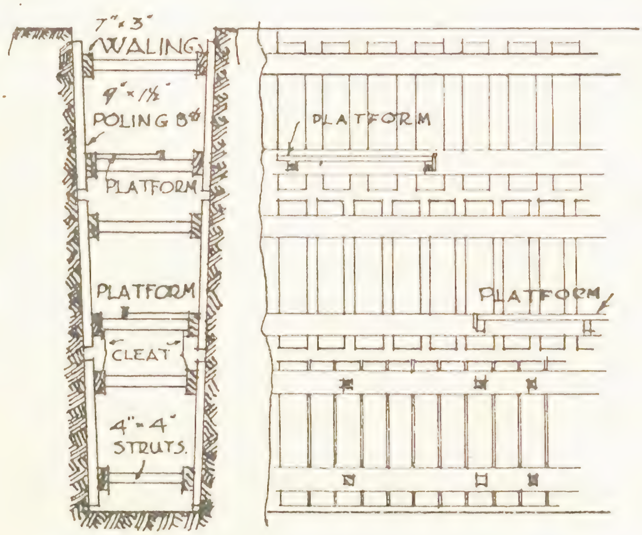


Fig. 76.—Timbering for deep excavation, showing platforms.

The timbering is carried out in stages of 4-foot depths, and assuming a trench 13 feet deep is required, this will necessitate three series of timbering. The same rules for loose and firm earth apply here, as in former instances. Thus in a trench 13 feet deep dug in ordinary firm soil, the first series of timbering will consist of 9 × 1½-inch poling boards, 4 feet in length, spaced a foot apart, held in position by 7 × 2½-inch waling pieces, strutted apart by 3 × 3-inch or circular struts.

The second series will consist of similar timbering, but the poling boards will require to be set closer together, and in the bottom series the poling boards may require to be butted. The throwing platforms already referred to consist of 7 × 2-inch boards fixed over the strut two-thirds of the width of the trench, and should be fitted with an upright edging to prevent the earth from falling back into the excavation. The situations of the platforms should be diagonal, not only with regard to each other, but on alternate sides of the trench.

Similar trenches to those last described for excavations for drains in loose ground will require their lower series horizontal sheeting strutted with the usual poling boards and struts, and the bottom series of timbering for such a trench will require to be fixed 3 inches in front of that above it, thus giving an excavation 6 inches narrower than the upper one.

This permits the poling boards in the bottom series to overlap those in the series above. It may also be necessary to form both these trenches with sides sloping in from the top.

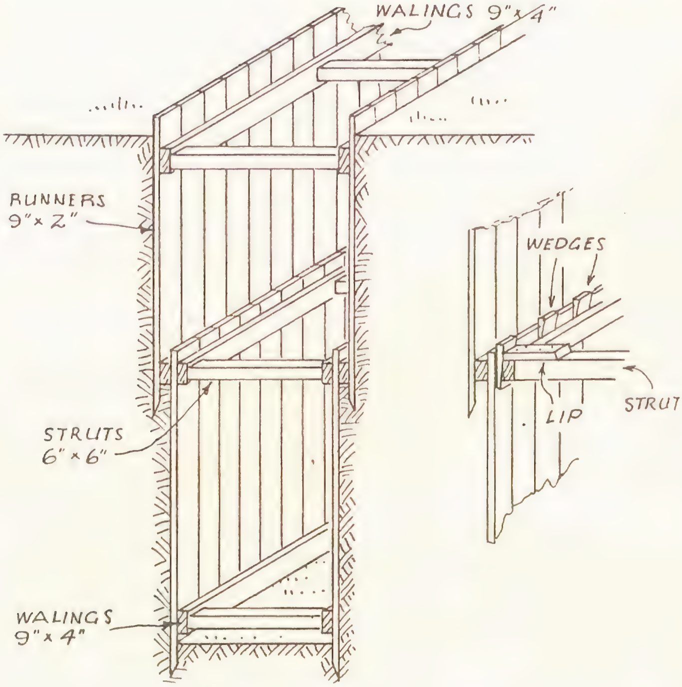


Fig. 77.—Sheeting and strutting trench in soft ground.

Stepped Excavations.—Timbering for trenches which required to be stepped owing to the sloping nature of the site require a special form of timbering. The length of the steps will depend, as has already been said, on the slope of the ground, and each section between the steps then becomes a separate section of timbering. This consists of $9 \times 1\frac{1}{2}$-inch poling boards placed upright at appropriate distances apart, held in position by 7×3-inch waling pieces of the necessary length for each section between the steps, two to each poling board, one at the top and the other at the bottom, and kept in position by 4-inch struts, two to each waling piece. Where steps are deep, resulting in a trench of greater depth than can be properly supported by a single system having poling boards of average length, the timbering must be composed of two series, the same in every respect as that just described, with the exception that the length of the poling boards will be reduced to admit of two series within the increased depth.

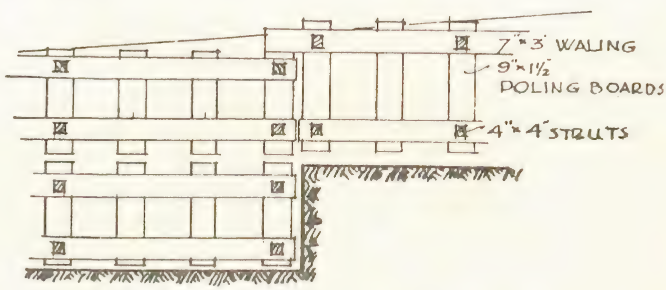


Fig. 78.—Timbering for stepped excavations

Shafts.—Vertical shafts are often required, extending down below the foundations of a building for lift wells and foundations for heavy steel stanchions. These shafts must be sunk in a series of stages, and may

really be regarded as trenches dug vertically. The sides must be sheeted, the sheeting being driven in in sections, each lower section of sheeting overlapping the one above it, the whole being kept in position by vertical posts at the angles, having 6 × 4-inch waling pieces cut in between these to hold the sheeting in position. Wide shafts will require intermediate struts and vertical supports as detailed for wide excavations.

Removal of Timbering.—The removal of the timbering is an important matter. As the stage at which this is permissible often coincides with that when the excavations are to be filled in, it is the custom, only too often met with, to leave a large proportion of the timbering in position. This cannot be considered a good practice, nor must the timbering be removed too soon on account of the fact that the cross struts interfere with the laying of the brickwork. The proper course to adopt in these circumstances is to cut in short props between the face of the brickwork and the poling board, the brickwork having been built up in the space between the cross strut, and then to remove the cross strut and build up in brickwork the spaces which they have occupied. The timbering may then be withdrawn stage by stage, as the brickwork is built up level with the top of each stage and the excavation filled in and rammed. Though, as has been said, it is not a good plan as a general rule to leave timbering in position, there are circumstances in which it is advisable to do so. These occur, as will be explained in the chapter on Piling, in waterlogged or shifting soils, and they become in the nature of permanent sheet piling, driven in to retain the shifting soil, and for this purpose require special treatment, including preservation against damp.

WEIGHT AND STRENGTH OF TIMBER

Name	Weight per cubic foot.	Ultimate Strength per square inch.		Modulus of Elasticity E.
		Tension.	Compression with grain.	
		Tons.	Tons.	Tons./sq. in.
Ash	48	4·5	4	700
English elm	35	2·7	3	700
Canadian elm	45	4	4	700
Spruce	30	2	3	500
Larch	35	4	3	500
Oak	55	5·5	4·5	700
Beech	48	5	3·8	600
Pitch pine	45	3	3	800
Yellow pine	30	1	2	650
Red pine	43	1	2	600
Greenheart	70	6	8	500
Hickory	50	3	4	800
Lignum vitæ	78	6	8	800
Bamboo	20	3	5	900
Ironwood	58	6	8	800
Blue gum	74	7	3½	—
Teak	45	2	2·3 to 5·4	800
Sabieu	57	2·5	4	1,100

CHAPTER 7

FOUNDATIONS AND FOOTINGS

FOUNDATIONS

Definitions.—Some confusion is liable to exist unless it be definitely decided to what the terms Foundations and Footings have application.

The term "foundations" has in the past generally been taken as meaning the concrete which is placed in the bottom of the trench, and on the top of which the brickwork or masonry wall is built. It is customary to give this brickwork a widened base, and the course composing this widened base up to the point at which the thickness of the wall itself is reached is termed the footings. So far as brick walls are concerned, these definitions are satisfactory.

Incidentally, it is of interest that the definition of foundation given in the London Building Act is as follows :

" The expression foundation (applied to a wall having footings) means the solid ground (or artificially formed supports) on which the footings of the wall rest."

Subsoils.—The nature and size of the artificial foundation which it is necessary to give to any building depend on the load and the nature and varying strength of the subsoil, and for our purpose it is sufficient if we consider subsoils of rock, chalk, gravel, clay and sand. These are the subsoils most frequently met with in building work.

Rock.—Rock and solid chalk will require very little if any reinforcement. Some filling in, however, with concrete will be necessary with such classes of rock as have fissures or faults. An additional item must be included in pricing for the extra labour involved in cutting rock. The foundations should be made as level as possible, when the walls may be built directly thereon. The foundation which consists of rock and a softer subsoil is one of the most difficult to build on. The soft portions may be arched over or concrete piers may be sunk or piles driven, as described later. Where the whole site shows inequalities of this nature, it will probably be found the least expensive method in the long run to build a reinforced-concrete raft over the whole site.

Chalk.—Solid chalk is practically as good as rock to build upon, but as in chalk underground springs are frequently encountered, with the

result that the chalk becomes softened in parts, it will therefore be found necessary to drain away the subsoil water. Also chalk is affected by the atmosphere to a far greater degree than is rock; consequently the foundations must be excavated to a depth at which the effect of the atmosphere is not felt. The majority of chalk subsoils will require concrete footings.

Clay.—Clays are of such a different nature that no hard-and-fast rule can be laid down for even the whole of any particular site. Firm, dry clay will carry heavy loads without any danger of subsidence, but the same clay in a very damp season will be liable to expansion in bulk, and clays damp at an ordinary time will be liable to shrinkage in a very dry season. Also any clay foundations under 4 feet in depth will be affected by heat and frost, especially where excavated soil is returned around the walls. Protection against these changes of temperature may be afforded by building a concrete pavement over this made-up earth.

Whereas all subsoils will require to be drained, a clay subsoil requires more care than others, as the extent of the drainage must not be such as to cause shrinkage, though this limitation is a difficult point to arrive at, clay however treated being liable to move. The safest thing where great weight is to be carried is to reinforce the foundations with concrete piling.

Sand.—Sand when compact and dry forms a good sound foundation, but if subjected to the effect of running water it must be confined laterally by sheet piling, preferably of metal. Quicksands and silts do not form suitable sites for building on, and such operations should not be considered in connection with them unless no other is to be found, when very considerable expenditure will have to be contemplated in enclosing the whole site to a considerable depth in sheet piling or driving piles to a firmer subsoil.

Gravel.—Gravel makes a good foundation, is not affected by the atmosphere, provides natural drainage, and has high bearing value.

Precautions should be taken to find out what is the nature of the subsoil underlying the gravel if the gravel is not deep, as gravel on a damp soil, say clay for instance, is not only compressible but may shift laterally, and is unhealthy owing to its preventing satisfactory subsoil drainage.

Treatment of Soft Soils generally.—Subsoils will be found which consist of a very soft soil of considerable depth, and in these circumstances a reinforced-concrete raft over the whole site may be found suitable. Piling over the whole site is an alternative and more expensive method of treatment. A combination of the two methods may give the greatest satisfaction. Where a soft subsoil overlies a hard subsoil, the most satisfactory method to employ is to sink shafts to the hard substratum, and to lay in concrete piers either arching over between these or building a concrete raft on the piers.

Resistance of Subsoils.—The following table of safe resistances of earth is given by Newman :

Description of Earth	Approximate safe maximum load in tons, per square foot
Bog, morass, quicksand, peatmoss, marsh land, silt	0– 0·20
Slake and mud, hard peat turf	0– 0·25
Soft, wet, pasty or muddy clay, and marsh clay	0·25– 0·33
Alluvial deposits of moderate depths in river-beds, etc.	0·20– 0·35
Note.—When the river-bed is rocky and the deposit firm, they may safely support 0·75 ton, but not more.	
Diluvial clay beds of rivers	0·35– 1·00
Alluvial earth, loams and loamy soil (clay and 40 to 70 per cent. of sand), and clay loams (clay and about 30 per cent. of sand), damp clay	0·75– 1·50
Loose sand in shifting river-bed, the safe load increasing with depth	2·50– 3·00
Upheaved and intermixed beds of different sound clays	3·00
Silty sand of uniform and firm character in a river-bed secure from scour, and at depths below 25 feet	3·50– 4·00
Solid clav mixed with very fine sand	4·00
Note.—Equal drainage and conditions are especially necessary in the case of clays, as moisture may reduce them from their greatest to their least bearing capacity. When found equally mixed with sand and gravel their supporting power is usually increased.	
Sound yellow clay, containing only the normal quantity of water	4·00– 6·00
Solid clay, marl and indurated sand, and firm boulder gravel and sand	5·00– 8·00
Soft chalk, impure argillaceous	1·00– 1·50
Hard white chalk	2·50– 4·00
Ordinary superficial sand beds	2·50– 4·00
Firm sand in estuaries, bays, etc.	4·50– 5·00
Note.—The Dutch engineers consider the safe load upon firm clean sand as 5½ tons per square foot.	
Very firm compact sand foundations. At a considerable depth not less than 20 feet, and compact sandy gravel	6·00– 7·00
Note.—The sustaining power of sand increases as it approaches a homogeneous gravelly state.	
Firm shale protected from the weather in clean gravel	6·00– 8·00
Compact gravel	7·00– 9·00
Note.—The relative bearing powers of gravel may be thus described : (1) compact gravel ; (2) clean gravel ; (3) sandy gravel ; (4) clayey or loamy gravel. Sound, clean homogeneous Thames gravel has been weighted with 14 tons per square foot, at a depth of only 5 feet below the surface, and presented no indication of failure. This gravel was similar to that of a clean pebbly beach.	
Rocks for foundations and general work	8·00–18·00
Rocks, sandstones that may be crumbled in the hand	1·50– 1·75

Subsoil Drainage.—Quite distinct from the subject of the water which collects on the surface of a site (already described in Chapter 1), there is the water which percolates under the surface and saturates the upper ground if it lies on an impermeable sub-stratum. Any site on which this causes dampness will require draining before the building is begun. Failure to observe this precaution will not only render the building damp, but may cause a settlement in the foundations in the event of any deep cutting being made in the neighbourhood, as the cutting may

drain water away and cause the subsoil to shrink. But subsoil drainage should not be overdone or it may cause deep movements of subsoil.

The method of dealing with this subsoil drainage is similar to that employed for surface-water drainage, but the pipes and trenches will require to be sunk to a lower level.

Fig. 79.—Methods of forming subsoil drains.

Trenches.—As open trenches for this purpose of the depth that would be required would be dangerous, after the bottoms have been cut to the required slope and the agricultural drainpipes laid therein, they are covered with either broken stones, gravel or ashes, when the earth may be returned. Cheaper forms of trenches may be constructed by forming squared conduits in the bottom of flat stone or slate, and the most economical, and in some subsoils quite serviceable, form of drainage trench is to be obtained by filling in the bottom of the trench with a foot depth of broken stone or clinker. Agricultural drainpipes used for this purpose require no jointing, but are laid butted, the joints being covered over with collars or strips of bituminous asphalt dampcoursing to prevent the soil finding an entrance through the pipes.

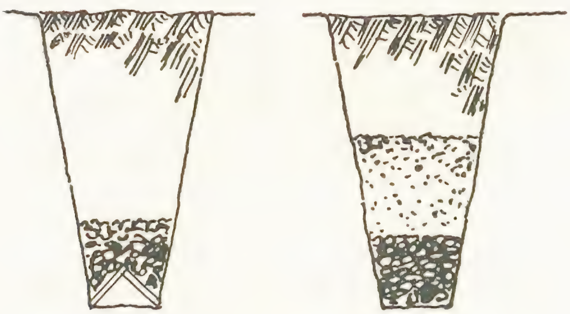


Fig. 80.—Methods of forming subsoil drains.

Either a drainage plan should be kept, or the positions of these pipes and trenches should be indicated by pegs or some other means, to enable any stoppage to be remedied. This may be caused either by the accumulation of silt, or on country sites by the roots of trees in growing pushing the pipes out of place. All such pipes passing under the foundation of buildings must either be in metal or the foundations should be arched over so that no pressure comes upon the pipes.

Inspection.—Before proceeding to lay foundations with concrete or to start building thereon, reference must be made to the by-laws and to the specifications in which there will be found clauses requiring that the Architect, and also possibly the District Surveyor, must be informed and their permission gained.

LONDON BUILDING ACT REQUIREMENTS

The following requirements are quoted from the London Building (Constructional) By-laws, 1952 :

" *Part IV.—Sites of Buildings, Excavations, Foundations and Voids beneath certain Floors*

" **4.01.** ***Preparation of Sites.***—No part of any building or chimney shaft shall be begun unless and until

" (*a*) the site of that part (including all ground supporting that part or aiding in the support thereof) is to the satisfaction of the district surveyor cleared of all material (whether above or below the surface of the ground) which consists of or is impregnated with fæcal, animal, vegetable matter or any other matter likely (having regard to the manner in which and the materials of which the building or chimney shaft is or is to be constructed) to affect adversely the building or chimney shaft or the use thereof, and

" (*b*) all excavations, voids and cavities in the site of that part (including all ground supporting that part or aiding in the support thereof) are so filled or otherwise treated, with such materials and in such manner as may, to the satisfaction of the district surveyor, be necessary for the purpose of preventing the stability of the building or chimney shaft from being affected adversely thereby.

" **4.02.** ***Excavations.***—All excavations made within a line drawn outside the external walls of a building or chimney shaft at a uniform distance therefrom of 3 feet shall be filled or otherwise treated with such materials and in such manner as the district surveyor may approve as being suitable.

" **4.03.** ***Covering of Sites.***—(1) The ground surface within the external walls of every building shall be covered with a layer of concrete, finished smooth on the upper surface and at least 6 inches thick :

" provided that the layer may be not less than 4 inches thick

" (*a*) if the concrete is laid upon a consolidated bed consisting of clinker, broken bricks or other similar material and being, to the satisfaction of the district surveyor, in all respects suitable ; or

" (*b*) if the concrete is in no respect inferior to that designated Grade III in by-law 3.07 and if the nature and condition of the ground is, to the satisfaction of the district surveyor, in all respects suitable ; or

" (*c*) if the concrete is in no respect inferior to that designated Grade III in by-law 3.07 and is reinforced in conformity with these by-laws.

" (2) Paragraph (1) of this by-law shall not apply to any building or part of a building

" (*a*) if and so long as that building or part of a building is used solely

" (i) for the fabrication or storage of steelwork ; or

" (ii) as a foundry ; or

" (iii) as a blacksmith's shop ; or

" (iv) for the milling or storage of timber ;

" (*b*) if and so long as that building or part of a building does not exceed one storey in height (exclusive of any gallery or platform) and

" (i) is open on two or more sides ; or

" (ii) is used solely for the storage of builder's materials or plant ; or

" (iii) is used solely as a single private garage, a greenhouse, a tool-shed or a cycle-shed and does not communicate by any door, window or other opening with any building to which paragraph (1) of this by-law applies.

" (3) Where in any part of a building the layer of concrete required by paragraph (1) of this by-law is also a floor of the building, that layer shall, without prejudice to the requirements of that paragraph, be constructed with such materials and in such manner as may, to the satisfaction of the district surveyor, be necessary for the purpose of preventing the building from being affected adversely by moisture from the adjoining earth.

" (4) Where in any part of a building the floor next above the ground is constructed of concrete and is so constructed as to leave an air-space between it and the ground, that floor may be deemed to be the layer of concrete required by paragraph (1) of this by-law if and so long as the air-space is, to the satisfaction of the district surveyor, adequately ventilated and so enclosed as to prevent its use for any purpose other than that of ventilation.

" **4.04.** ***Voids beneath Certain Floors.***—(1) Where in any part of a building the floor next above the ground is constructed of wood, that floor shall be so constructed as to leave an air-space not less than 6 inches deep between the level of the underside of the joists of that floor and the level of the upper surface of the layer of concrete required by paragraph (1) of by-law 4.03 or the level of the ground itself (as the case may be), and that space shall, to the satisfaction of the district surveyor, be adequately ventilated to the open air by means of air bricks or otherwise.

" (2) The provisions of paragraph (1) of this by-law shall not apply where a membrane impervious to moisture is provided between the concrete and the floor and any battens which may be provided are impregnated with creosote under pressure.

" **4.05.** ***Foundations.***—(1) Every wall, pier, column, post and beam of a building and every chimney shaft shall, unless supported in some other suitable manner and except as otherwise provided by paragraphs (4) and (5) of this by-law, be supported by foundations of concrete or reinforced concrete.

" (2) Every such foundation shall be of such thickness, not being less than 6 inches as may, to the satisfaction of the district surveyor, be necessary for the purpose of compliance with the provisions of by-laws 1.04 and 1.07.

" (3) Every such foundation shall extend horizontally

" (*a*) in the case of a wall or pier, to a distance beyond each of the side and end faces of the wall or pier, of not less than the thickness of the wall or pier at the underside of the course which rests on the foundation or the course immediately above the footings (as the case may be) or to such greater or less distance as may, to the satisfaction of the district surveyor, be necessary or adequate for the purpose of compliance with by-laws 1.04 and 1.07 ; or

" (*b*) in the case of a chimney shaft, to a distance beyond each face of the brickwork of the chimney shaft, of not less than the thickness of the brickwork of the chimney shaft at the underside of the course which rests on the foundation or the course immediately above the footings (as the case may be) or to such greater or less distance as may, to the satisfaction of the district surveyor, be necessary or adequate for the purpose of compliance with by-laws 1.04 and 1.07.

" (4) Any external wall which is adjacent to or adjoins another external wall or a party wall shall be supported by foundations of such materials, form and construction as the district surveyor may approve as being suitable, having regard to the particular circumstances of the case.

" (5) Where a building or part of a building not more than one storey high is so constructed that a boundary wall in existence at the time that building or part of a building is begun becomes wholly or partially a wall of that building or part of a building, that wall may, if it is to the satisfaction of the district surveyor of adequate stability, be deemed to comply with the provisions of this by-law, and shall, if it is not to the satisfaction of the district surveyor, of adequate stability, rest on foundations of such materials, form and construction as the district surveyor may approve as being suitable, having regard to the particular circumstances of the case.

" **4.06.** ***Pressure on Foundations.***—The pressure on concrete or reinforced concrete foundations shall not exceed the pressure specified in Table IX for the Grade of concrete specified in that Table.

" **4.07.** ***Piling.***—All piling used in connection with the foundations of any building or chimney shaft shall, to the satisfaction of the district surveyor, be of adequate load-bearing capacity and be in all other respects suitable.

" **4.08.** ***Pressure on Ground.***—No part of the ground which supports or aids in the support of any building or chimney shaft shall be subjected to pressure (whether exerted by any part of the building itself or otherwise) other than such as may be approved by the district surveyor.

" **4.09.** ***Pressure from Adjacent Ground.***—If the ground adjacent to any building or chimney shaft exerts pressure upon or causes the application of load to any part of that building or chimney shaft, that building or chimney shaft shall be so constructed as to be capable of safely sustaining and transmitting that pressure or load without exceeding the appropriate limitations of permissible stresses.

TABLE IX

PRESSURE ON CONCRETE OR REINFORCED CONCRETE FOUNDATIONS

Designation (as specified in by-law 3.07).	Pressure in tons per square foot.
Grade I	50
Grade II	44
Grade III	39
Grade IV	20
Grade V	15
Grade IA	96
Grade IIA	80
Grade IIIA	64
High Alumina cement concrete	96

The pressure for concrete of mixes intermediate to those respectively specified in Tables V and VI of by-law 3.07 shall be ascertained by proportion from the pressures for concrete of the two nearest specified mixes, such proportion being based on the ratio of the sum of the volumes of the fine and coarse aggregate, each mix being measured separately, to the volume of cement.

FOOTINGS

Spread Footings.—The spread footings of the wall above, as distinct from the concrete footings, are described in Chapter 1, Vol. II, but it is simpler at this stage if we consider the two subjects together generally in order to arrive at an easy method of ascertaining the depth of the concrete footing for average conditions of subsoil. Walls which carry normal loads will rarely require to be more than 2 feet 3 inches thick at the base, and between this base and the concrete there is a series of brick offsets, varying in number in accordance with the thickness of the wall.

The width of the concrete bed is taken as 6 inches wider than the lowest offset of the brick wall, and the width of this lowest offset course is double the thickness of the wall above. Each offset is $2\frac{1}{4}$ inches.

A simple method of obtaining the depth of the concrete is the following: a cross-section of the wall with its offset footings is drawn, and the top line of the concrete footing is also shown, of a correct length to represent the width. A line at

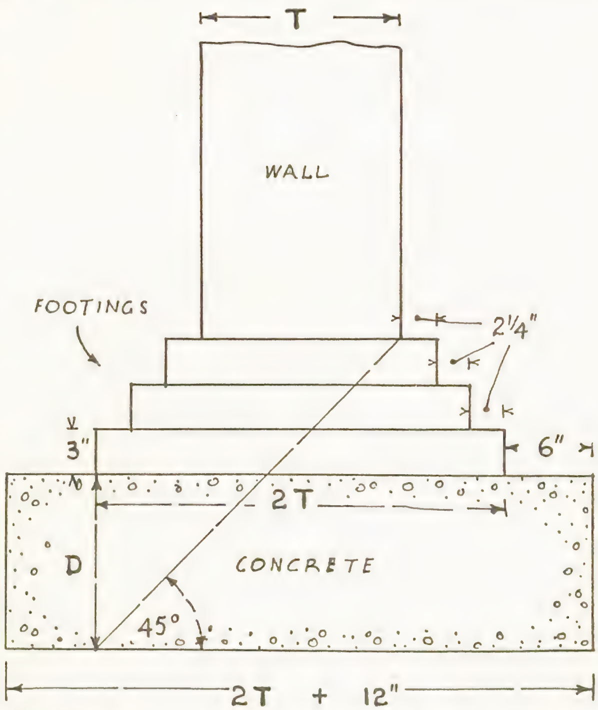


Fig. 81.—Graphical method of setting out wall foundation.

45° is then drawn from the edge of the base of the wall until this meets the line of the bottom course of brick footings projected downwards. This point of junction of these two last drawn lines gives the level of the bottom of the concrete footings. The depth of the concrete thus shown is to be taken as a minimum depth for any thickness of wall, as shown in Fig. 81.

The composition of the concrete used in the footings of walls is dealt with in Chapter 8, Vol. II, on concrete, but the result of using concrete of poor quality may be noted here, as having reference to the need for these spread footings. If a wall were to be continued down of the same thickness or spread until it reached the concrete, and the concrete were of a poor mixture, it would have a tendency to cause the concrete to sink at its centre and to be turned upwards at its outer edges, whereas the spread footings of brickwork lessens this tendency towards bending of the concrete.

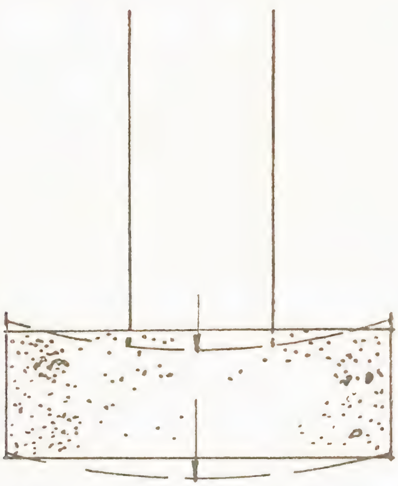


Fig. 82.—Tendency of load to bend foundation.

To increase the rigidity of the bottom course of the step footings of the brick wall, this course is often doubled, and this again, in opposing the rigidity over a wider area on the upper surface of the concrete, lessens the bending tendency.

Brick footings are built in heading courses in order that each brick may obtain a wall hold of three-quarters of its length and thus increase the rigidity.

This rigidity of spread concrete and spread brick footings of twice the thickness of the wall plus 12 inches overcomes any tendency of the wall to lean. A leaning tendency in a wall may be occasioned by undue outward pressure from the roof timbers or the floor joists.

Hollow Walls.—The method of forming footings for hollow walls is described in Chapter 1, Vol. II, but so far as the width of the concrete footing is concerned it may be stated here that the Building Regulations regard a hollow wall formed of two 4½-inch brick walls and a 2-inch cavity as a 9-inch wall, and one having a 9-inch inner wall, a 4½-inch outer wall, and a 2-inch cavity as a 13½-inch wall. Therefore, the bottom course of the brickwork in the first instance becomes 18 inches wide, and in the second 27 inches wide; the concrete respectively therefore being 2 feet 6 inches and 3 feet 3 inches wide.

Concrete Footings.—Where it is desired to form the spread not only of the concrete foundations as previously described, but also of the wall itself, in place of the offset courses of brickwork, the dimensions of such foundation are found in a similar manner to the graphic method described for obtaining them in brickwork and

concrete. That is to say, a distance of 12 inches below the last course of the brick wall is marked off, and this gives the top line of the concrete footing of the full width of the trench. From the centre point of this top line of the concrete the thickness of the wall proper is marked off on each side. This provides the spread of the footings now to be built in concrete, in place of the brick offset. A line at 45° from the bottom course of the brick wall drawn until it cuts a vertical line projected downwards from the widest point of the spread footings to the wall will, where it cuts the line at 45°, give the depth of the concrete. The full width of the concrete at its deepest portion will be 6 inches wider than the width of the spread at its widest part.

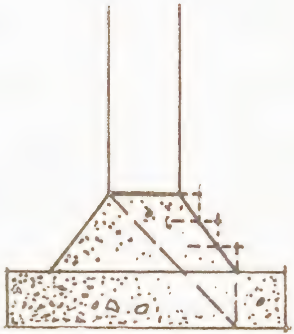


Fig. 83.—Spread to concrete wall.

Footings for Special Conditions.—As has been explained in Excavations, where a site slopes it is necessary to arrange the trenches and consequently the concrete in steps; these steps should be of short lengths and regular height so far as is possible. The purpose of this is to minimise any possibility of unequal settlement. Though sometimes step footings are seen having the concrete footing cut off vertically in line with the face of the stepping of the excavation, this is a faulty practice. The concrete should be laid in vertically as well as horizontally, having a width or overlap of not less than the normal depth of the concrete beneath the walls. It is essential that all foundations be of an exact level.

Foundations for Steel Stanchions.—Into the special shafts prepared for the foundations of steel stanchions, special types of concrete footings must be set. Where the weight to be carried is not excessive, the work may be bedded directly on to the concrete base, in which it will be necessary to fix ragbolts in the exact position required and shown on the steel-frame detail drawing. These ragbolts will fit through holes prepared for them in the base of the stanchion or column. To spread a heavy load a steel joist grillage is often used, as in Fig. 91.

Where the stanchion is taken down below the level of the ground, it should be cased in concrete to prevent rust, though if the depth is excessive it may be found less expensive to build the concrete up to the ground level, and base the stanchion at that point.

SURFACE CONCRETE

Over the whole of the surface of any area covered by a building the top soil must be excavated and concrete laid in to a depth of not less than 6 inches or 4 inches if reinforced. The omission of this concrete would render the penetration of damp into the interior of the building more

possible, and also cause the growth of vegetation and fungi under the building and on the woodwork used in the floors, which give rise to the worst disease which a building is capable of suffering, namely, Dry Rot. This disease will, if permitted to go unchecked, in a surprisingly short time attack and destroy all the woodwork used in the building. A proper realisation, therefore, of the importance of this surface concrete under a building would convince any intelligent contractor that it is folly to attempt to save a few pounds by omitting a certain number of cubic yards of concrete, and at the same time to spend many pounds in providing and erecting woodwork in a building which will eventually be destroyed.

Further, damp being permitted to rise in a building is the cause of serious illness to the unfortunate occupants, and whereas it may be thought that the introduction of a dampcourse alone in the walls is sufficient to prevent damp rising up the walls, this is not so if the surface concrete is omitted.

FOUNDATION TYPES

Foundations are required under walls, piers and columns, or stanchions. They should be designed to distribute the load on the subsoil so that there is no excessive or unequal settlement and that the foundations are not disturbed by shrinkage, water or atmospheric changes. Slight uniform settlement is no disadvantage, but unequal settlement causes cracks, leaning and bulging, and may endanger the stability of the structure.

If the load is a vertical compressive load, then the compressive stress or load imposed on the ground (C) is found by the simple formula

$$C = \frac{L}{A} \quad \text{where L is total load at foundation level,}$$

$$\text{and} \quad \text{A is area of foundation.}$$

Thus, if a wall foundation is 2 feet wide and transmits a direct compressive load of 18 cwts. per foot run, then, since 18 cwts. is the load on 2 square feet—

$$C = \frac{18}{2} = 9 \text{ cwts. per square foot.}$$

The above assumes that the foundation is uniformly loaded, but many foundations bear a heavier load on one side than on the other. A retaining wall is one such case, and a tall chimney subject to high wind pressure is another. Another case is a house wall with floor and roof loads supported on the inner half of the wall, but in this case the eccentric load, as it is called, is not great in proportion to the strength of the foundation and bearing value of ordinary subsoils, and we may ignore it.

Bearing Values.—Newman's table has already been given. The

table on page 113 from the London Building Act is shorter, and covers all subsoils met with in the London County area.

It does not follow that the subsoil is in every case fit to bear the above loads. In some cases London clay will not safely bear more than 3 tons per square foot. For small buildings, however, the foundation loads seldom exceed 1 ton per square foot.

Ground Bearing Test.—For heavy foundation loads, or where the bearing value of the subsoil is uncertain, a bearing test is sometimes made, as in Fig. 88, but this is a specialist's job. For moderate loads it is safe to rely on loading the ground well within the tabular bearing value, as shown above.

Wall Foundations.—The standard method of finding the foundation dimensions for ordinary walls is illustrated in Fig. 81. The following rules apply to this standard method:

The thickness (T) of the wall decides the number of courses of footings, width of bottom course of footings and width and depth of cement concrete mass foundation.

Brick footings project $2\frac{1}{4}$ inches each course on each side. There is a course of footings for each half-brick thickness of wall, so that the width of the bottom course of footings is twice the thickness of the wall at its base. The concrete foundation projects 6 inches on each side of the footings. From this it follows that:

$$\text{Width of concrete} = 2T + 12 \text{ inches.}$$

The depth of concrete is determined by drawing a line at 45° from either edge of the wall base to a point where it intersects a vertical line carried down from the edge of the bottom course of footings.

From the above method, concrete foundation widths for various thicknesses of wall are:

Thickness of wall.	Width of concrete.
9 inches	2 feet 6 inches
$13\frac{1}{2}$ inches	3 feet 3 inches
18 inches	4 feet 0 inches
$22\frac{1}{2}$ inches	4 feet 9 inches

The depth of concrete found as described above obviously varies with brick and joint thicknesses, but should not be less than 9 inches if unreinforced.

FOUNDATIONS FOR LIGHT LOADS

House Foundations.—For houses and other light structures with load-bearing walls the foundation usually consists of brick footings on mass (unreinforced) concrete, as shown in Fig. 84, but this type is not always adopted. On strong reliable ground it may be sufficient to build on footings only, omitting the concrete, as in Fig. 84 (top left).

The foundation must be taken down to a firm bottom where the subsoil is not only of adequate strength, but also secure against shrinkage,

swelling and other movements. In Fig. 84 four cases are illustrated. The depth of 2 feet should be taken as a minimum to avoid ground movements due to weather conditions. Fig. 84 (top, right) shows a foundation for a 9-inch wall on ground of moderate strength. It has a depth of 3 feet, which would be suitable where surface shrinkage might be anticipated.

The surface soil is sometimes followed by a stratum of weak soil, such as fine sand. Beneath this a hard subsoil will be found, perhaps many feet below the surface. Fig. 84 (bottom, left) illustrates such a case, and how the foundation must be taken down to this firm subsoil.

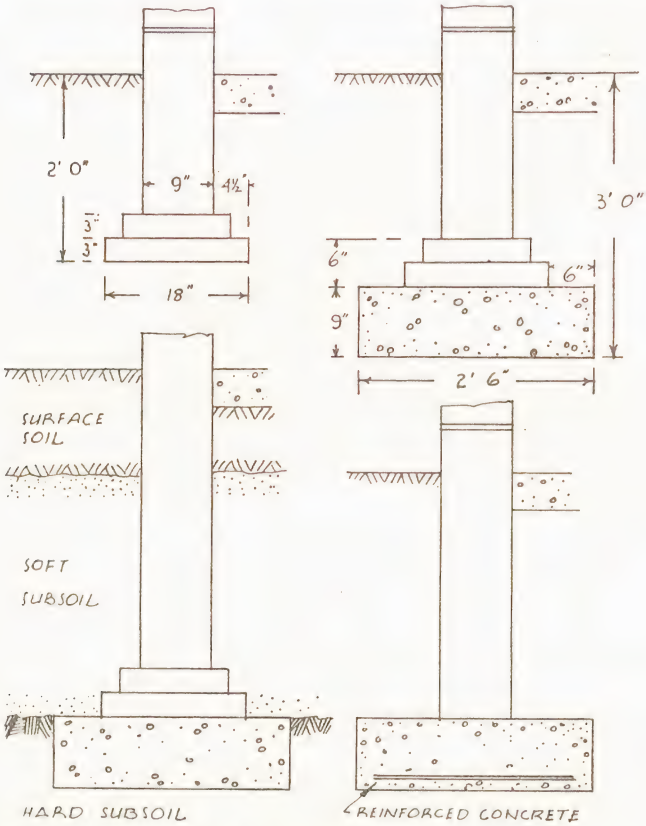


Fig. 84.—Wall foundations.

(*Top, left*) Brick footings on firm ground. (*Top, right*) Brick footings and mass concrete. (*Bottom, left*) Deep foundation. (*Bottom, right*) Reinforced-concrete foundation.

On rather weak subsoil it is economical to have a reinforced-concrete foundation as in Fig. 84 (bottom, right). This foundation forms a continuous beam which will carry the wall over any exceptionally weak spots in the subsoil and so prevent unequal settlement. For this purpose a fabric reinforcement is suitable such as expanded metal or a welded wire fabric.

Light Reinforced Rafts.—For certain types of weak ground the building may be erected on a reinforced concrete raft. This is a slab of concrete 6 inches to 9 inches thick, suitably reinforced. A detail is shown in Fig. 86. The raft foundation is suitable on filled ground, though such ground should be well consolidated. The effect is to obtain maximum spread of the loads. Notice that the reinforcement is placed near the top of the slab to take the tension due to upward ground pressure. The slab is thickened under the walls to form ribs which are reinforced near the bottom to take the tension due to the wall loads.

This type of raft is not suitable on clay at surface level, owing to the

shrinkage movements which occur with clay on the surface. With a clay site it is necessary to take the foundation down beyond shrinkage level—usually 4 feet at least. A reinforced-concrete strip foundation is suitable for such a condition, as shown in Fig. 84 (bottom, right).

FOUNDATIONS FOR HEAVY LOADS

Complex calculations and considerable experience are involved in the design of foundations for heavy loads. Safety must be combined with economy, and exact knowledge of a great variety of conditions is necessary to achieve this.

On strong subsoil not subject to shrinkage or other movement the

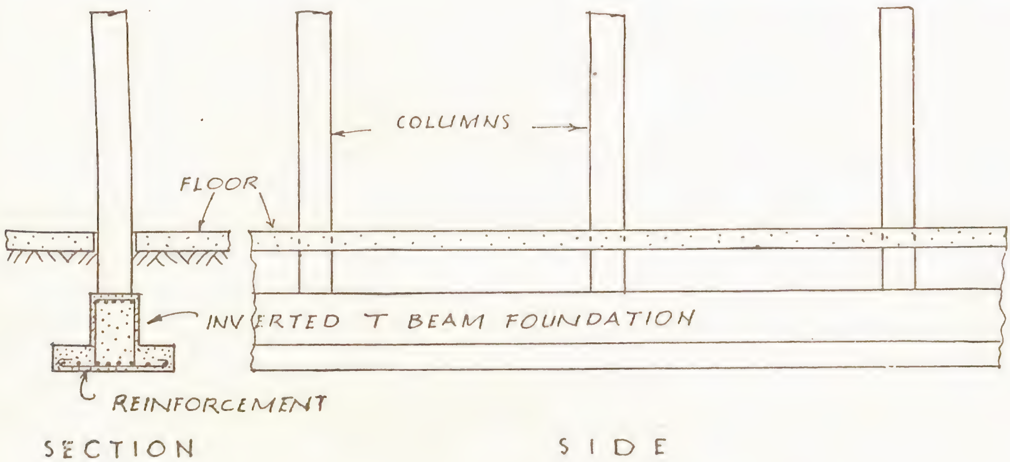


Fig. 85.—Foundation to columns. Inverted tee beam in concrete.

ordinary reinforced-concrete foundation is suitable for load-bearing walls.

For columns bearing moderate loads a square foundation reinforced with fabric near the bottom is suitable. For heavy loads column foundations may be of reinforced concrete or of the steel grillage type. Both enable a sufficient load spread over the ground to be achieved with a comparatively shallow foundation, thus economising excavation and concrete. A reinforced-concrete column foundation is shown in Fig. 90. Notice how the column reinforcement is taken down into the foundation. A steel grillage foundation is shown in Fig. 91. This consists of two tiers of rolled-steel joists, the upper tier being the deepest. The joists are secured by bolts passed through distance tubes. The concrete surround should be at least 3 inches thick to protect the steel.

Beam Foundation.—Where columns are fairly close together a beam foundation is suitable, as shown in Fig. 85. This also serves as a tie to the columns.

Heavy Rafts.—On certain sites with heavy structural loads it may be found that the average load per square foot for the site is almost equal to the safe loading for the ground. A strong reinforced-concrete raft is most suitable for this condition, though it is a costly foundation. Such

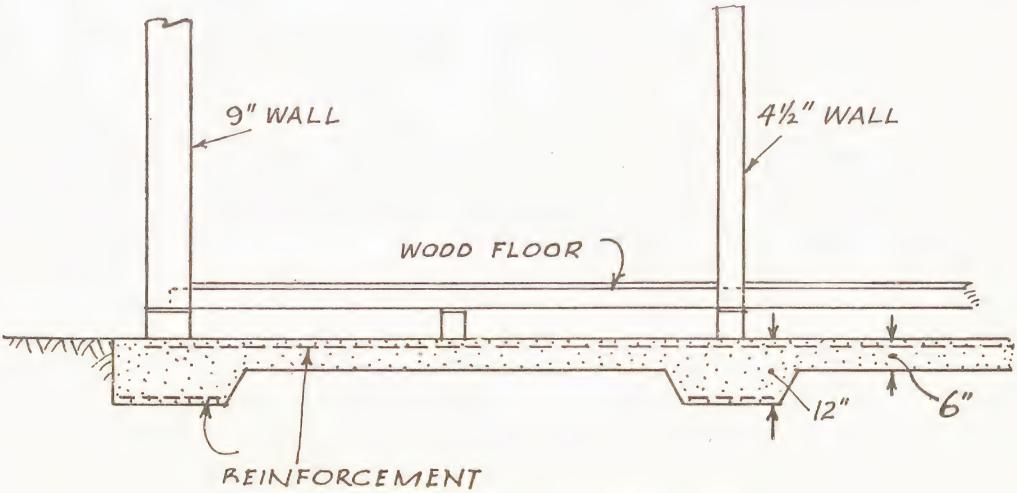


Fig. 86.—Reinforced-concrete raft foundation.

a raft is illustrated in outline in Fig. 89. Beams run under the columns so that the raft is like an inverted floor slab, the loading consisting of the upward pressure (reaction due to structural loads) of the ground. The floor slab may rest on filling or a cellular construction may be adopted, the floor slab spanning between the raft beams.

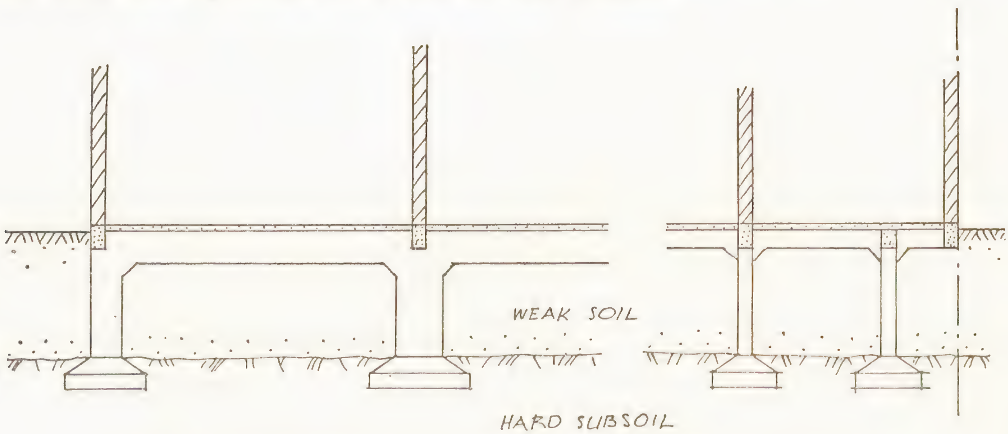


Fig. 87.—(*Left*) Column and beam foundation. (*Right*) Cantilever foundation.

Column and Beam Foundation.—Where there is a shallow stratum of weak soil, reinforced concrete columns may be formed in the ground, taking the foundation down to a strong subsoil, as shown in Fig. 87. These are connected at the top with beams on which the walls are built.

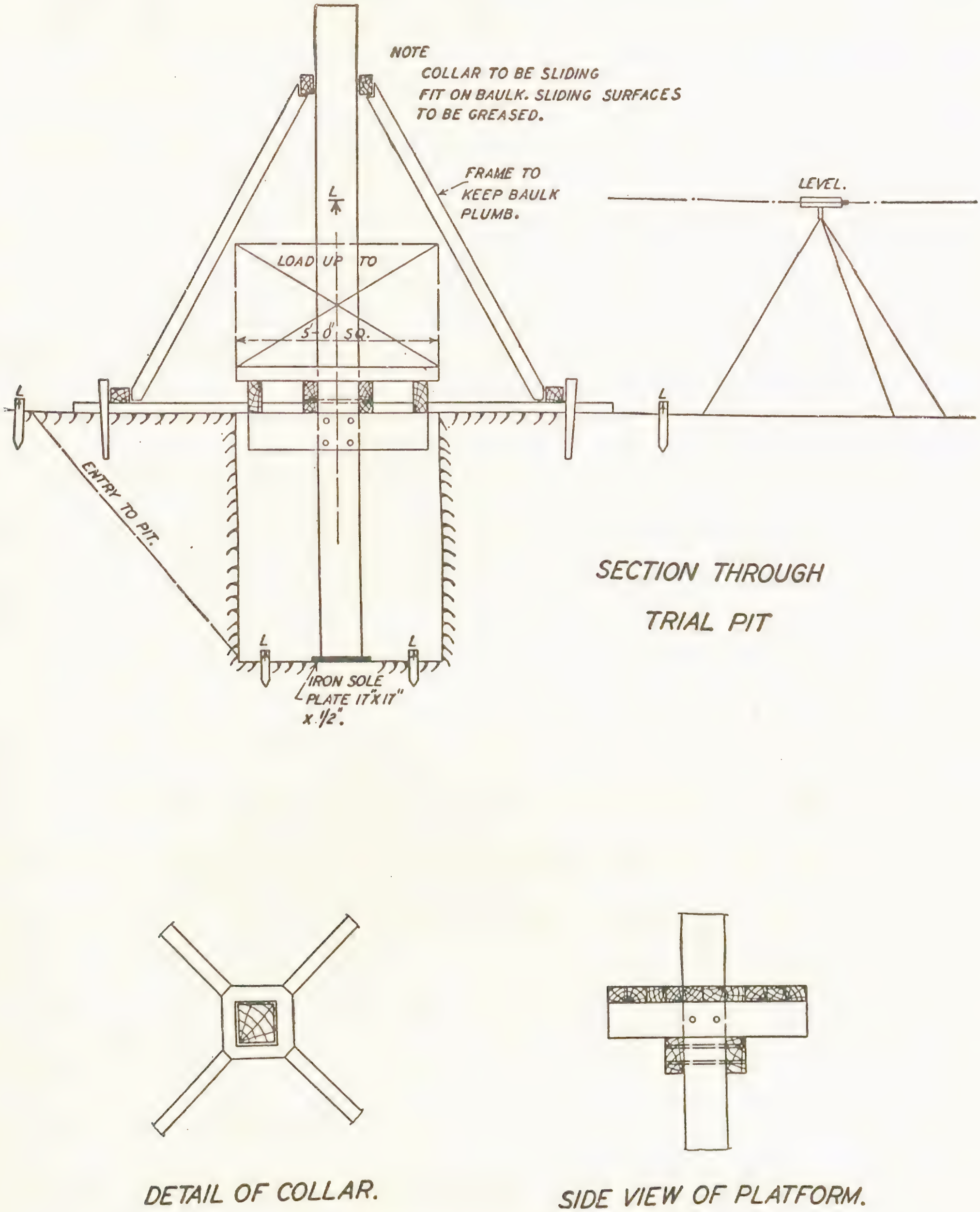


Fig. 88.—Bearing test for subsoil. (See page 124.)

Cantilever Foundation.—In some cases it is impossible to allow the load to rest on the ground underneath the wall or column. This may occur against a boundary where the foundation cannot be projected beyond the boundary, or over an existing basement, railway tunnel, etc. In such a case a cantilever system of support is adopted, as shown in Fig. 87.

Where heavy loads have to be carried and a strong subsoil is to be found only at considerable depth, piling is necessary, as described in Chapter 8.

Bearing Tests.—Knowledge of existing foundations on ground of a similar nature is the best guide in deciding the bearing strength of subsoil. Trial holes or borings should be taken out to ascertain the nature of the subsoil. A 2-inch hand-boring auger is useful for this purpose, as it enables a number of samples to be rapidly taken.

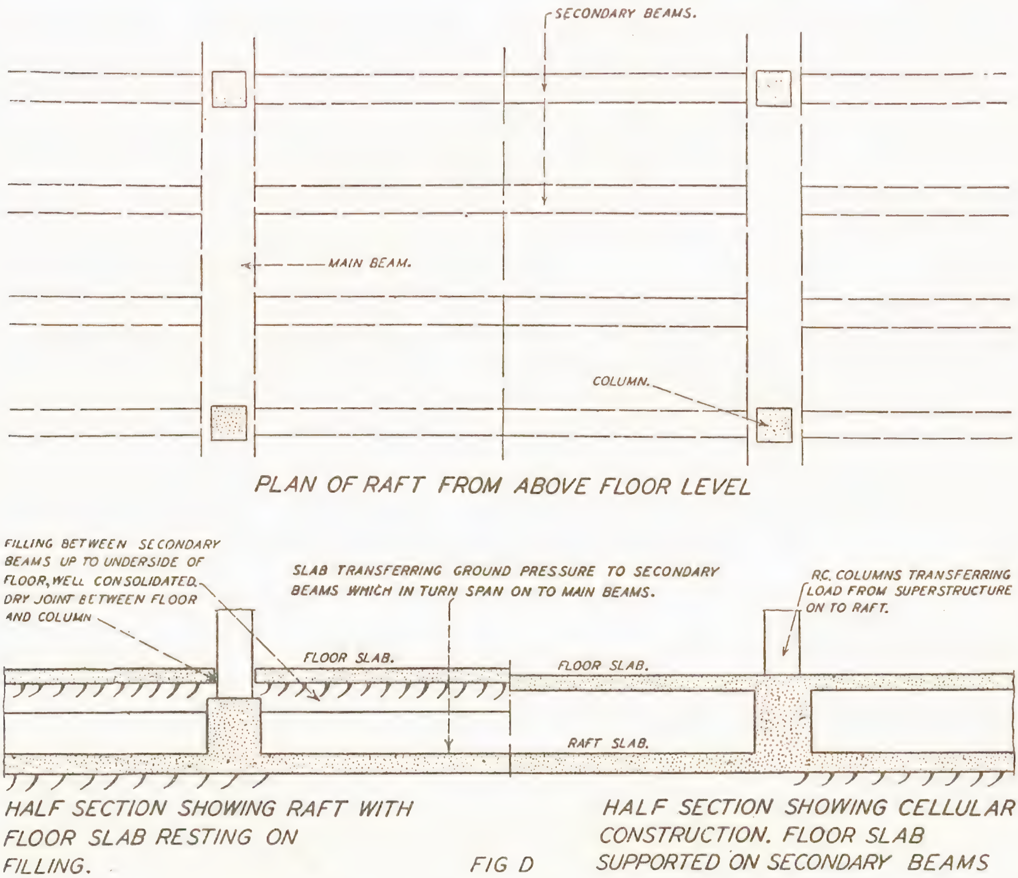


Fig. 89.—Reinforced-concrete raft with main and secondary inverted beams.

Where the bearing strength of the subsoil is uncertain tests can be made by loading the ground. There are several methods. A good practical method used by the British Reinforced Concrete Engineering Co., Ltd., is illustrated in Fig. 88. The area to be loaded should be as large as possible. The baulk to which the load is applied should be placed into position, but not driven. The load should be applied gradually, and when fully loaded it should be left for three weeks or until full settlement has taken place. Before removing the load the pit

should be flooded, and final readings taken after two days, the first readings being taken when the unloaded baulk is placed in position. A full log of readings at all points marked "L" should be kept for the duration of the test, taking readings at frequent intervals both of loading and settlement. The curve of loading and settlement should be plotted as a graph, and the resulting curve will usually show an intensity at which the ground "breaks down," and an ample factor of safety should be allowed on this figure.

CALCULATION OF FOUNDATION LOADING

This consists of calculating the load per square foot and arranging the foundation to spread the load over the subsoil so that the latter is loaded well within its safe bearing strength. The following is an example of the calculations for the foundation to a brick wall $13\frac{1}{2}$ inches ($1\frac{1}{2}$ bricks) thick:

Example.—Brick wall $13\frac{1}{2}$ inches thick, 20 feet high.

Roof load on wall		5 cwt. per foot run
Floor load on wall		12 cwt. per foot run
Wall load on concrete foundation:		
Weight of $13\frac{1}{2}$-inch wall	135 lb./square foot	
Multiply by height .	20 lb./square foot	
	2,700 per foot run	
	=	25 cwt. per foot run
So total load on concrete is		42 cwt. per foot run

This is well within the bearing strength of even a poor-quality cement concrete, so there is no need to investigate this point further.

To find the load on the subsoil, add to the above total the weight per foot run of the concrete. In this case the concrete foundation is 3 feet 3 inches wide by $11\frac{1}{4}$ inches deep. Say, $3\frac{1}{4} \times 1 = 3\frac{1}{4}$ cubic feet. Taking the weight of mass concrete as 1 cwt. per cubic foot, this gives $3\frac{1}{4}$ cwt. per foot run. Add this to the load found above.

	42 cwt. per foot run
	$3\frac{1}{4}$ cwt. per foot run
Divide by area	$3\frac{1}{4})45\frac{1}{4}$
Load on subsoil, say, ...	14 cwt. per square foot

Consulting the table of safe loads on subsoils (see page 110), we see that any subsoil of from moderate bearing strength will safely take this load.

It must be remembered, however, that there are other factors besides bearing strength to consider. The depth of subsoil at foundation level must be beyond the reach of swelling and shrinkage due to weather

conditions, and the subsoil must not squeeze out under load. Some subsoils (fine sand, for example) need to be laterally confined by retaining walls or sheet piling.

FOUNDATIONS FOR STEELWORK

In steel-framed buildings the general contractor will be provided with a steel frame diagram, which will show the exact position of the centre

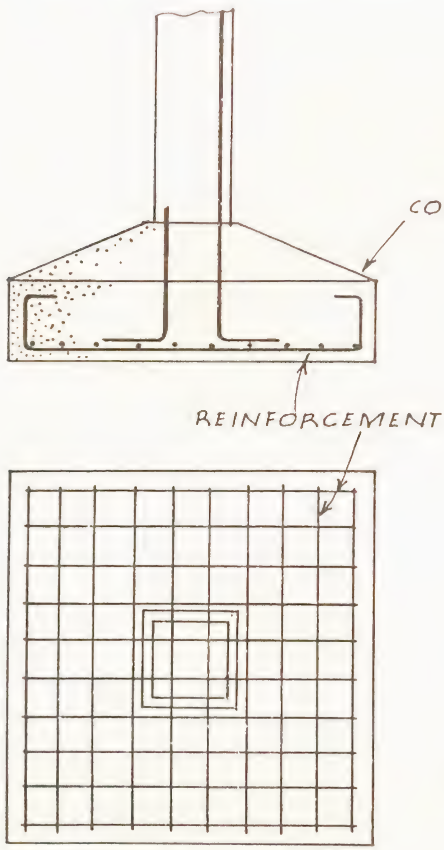


Fig. 90.—Reinforced concrete column foundation.

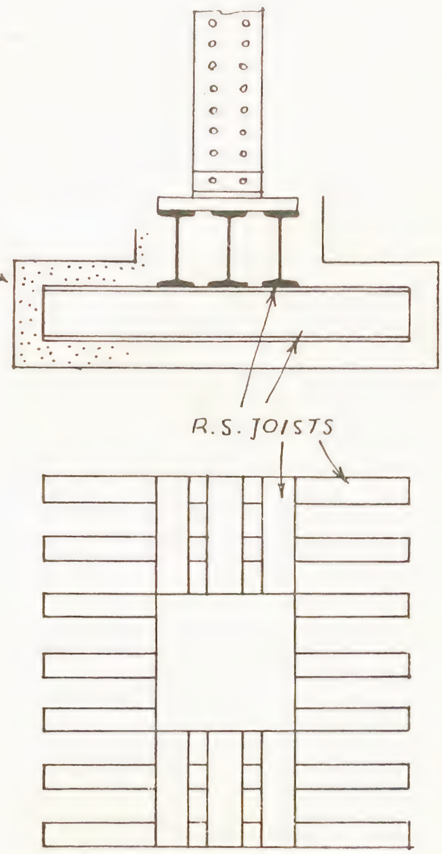


Fig. 91.—Steel grillage joist foundation.

lines of the stanchions. The positions of the excavations of these foundations may be obtained by the use of a template, and extreme accuracy in locating these is essential, as the steel will arrive on the site already cut to the lengths required. Any subsequent alteration necessary from inaccuracy in setting out the foundations will obviously have to be made to the foundations.

In this connection it is a useful point to notice that a steel tape should be used in preference to a linen one.

FAILURE IN FOUNDATIONS

Failure occurs in foundations mainly from the weight of the wall supported being greater than the resistance of the soil. This may show itself in the subsidence of the entire wall or only in portions thereof. On the other hand it may result in a leaning movement of the wall. Instances have been known where the whole building has slid from its original position owing to the subsoil shifting. Other causes of settlement in foundations are the withdrawal of the water from subsoils saturated at the time of the erection of the building ; the atmospheric action on certain classes of soil reducing their nature from sound solid soil to a soft mud ; and points of local weakness in the soil.

It should be borne in mind that the leaning of walls is not always occasioned by faults in foundations, but may be due to internal pressure caused by the roof, floors, etc. Trial holes in the neighbourhood of any cracks which may appear in the walls will decide the point as to whether there is any unequal settlement in the foundation, and if there is none there will be no necessity to underpin, but the wall will require pulling back into its proper position in the manner which is described later in the chapters dealing with brickwork, and some form of buttressing added on the outside or tying inside, to counteract the undue strain from the interior.

The remedy for the settlement in foundations has been dealt with in every case, except sliding. This will only be met with, as a rule, on a sloping site, though it did actually occur in one known instance on a site which was formed of a made-up terrace, the first indication of trouble being a bank rising in the middle of the tennis-court formed below the terrace. The usual cause is the sloping of the substrata. These when weighted become detached and slide. Whilst a cure is to be found in driving in piles through the upper strata into the lower to prevent the sliding, probably the best preventive is the erection of an efficient retaining wall.

CHAPTER 8

PILING

PERHAPS there has been more development in the matter of piling than in any other trade. This is probably due to the greater weight of the buildings now erected, the increased depth of basements, sub-basements and foundations, and the large amount of boring for underground railways and deep sewers which has been undertaken in recent years.

Whereas in the past piling consisted almost entirely of wooden poles, either circular or squared, piles are now to be obtained in concrete, both pre-cast and cast on the job, and metal, both individual and composed in the form of sheet piling.

The development in the use of piles has also created considerable development in the machinery used in conjunction with them

PILES

Piles are required to afford additional support to foundations where the subsoil is of such a nature that it may be affected by atmospheric conditions or by underground water, with the result that they afford insufficient stability or resistance to the vertical weight of the building. Without going too deeply into the mathematics of the subject, it will be gathered that the matter of supporting the weight of a building resolves itself into opposing that weight with a force greater than that of the weight, and if this force is not supplied by the natural resistance or strength of the subsoils, it is obtained by reinforcing the subsoil by driving piles into it. Piles are also driven into soils which have a tendency to slide laterally when the weight of the building is superimposed. The nature of the assistance given in such conditions is that of a pin or dowel, preventing the different substrata from sliding one over the other. Again, when the site of a building is situated on marshy land or running sand, the whole site is encased in piling, and for this sheet piling

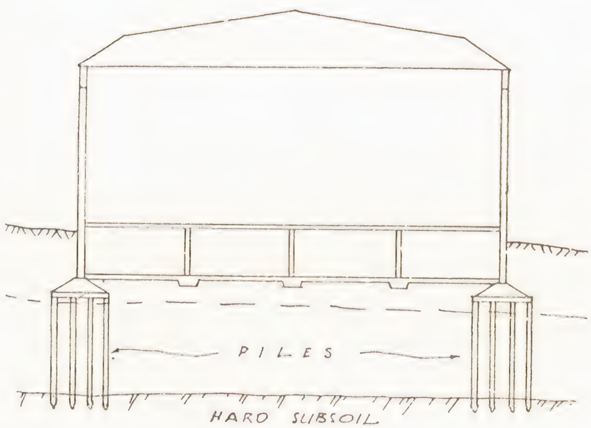


Fig. 92.—Main stanchions on piled foundation.

is used. When isolated supports under piers or columns are required, piles are driven in in groups affording support to these points only, and are termed *Clustered Piles*.

Consolidated Piles.—A term sometimes used when piles are driven all over the site, irrespective of what weight is to be superimposed, is that of consolidated piles.

When the depth of the unsuitable soil is too great for conveniently workable lengths of piling to reach the solid earth below, they are driven in so close together that they offer a resistance horizontally to movement in that direction. These are described as *Resistance or Friction Piles*.

Bearing Piles is the name given to piles used in the ordinary sense of bearing vertical weight.

Timber Piles.—For ordinary building work piles are composed mostly of oak, though elm, beech, larch, pine, and where it can be obtained teak, are all suitable timbers, though the last is generally prohibitive on account of cost. In the construction of docks and in positions where the timbering is constantly under water the use of teak is advisable, though greenheart and creosoted pine are also used for this work. Oak, by reason of its strength, will stand driving better than any other wood; but as straight lengths of timber are desirable, pine, which can be obtained in 90-foot to 100-foot lengths, with diameters up to 18 inches at the butt end and up to 12 inches at the thinner end, affords the most economical timber for pile driving.

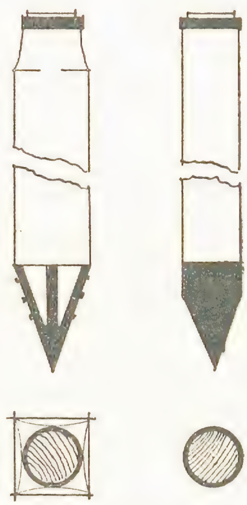


Fig. 93.—Timber piles.

Dimensions.—Piles are in use both circular and square, and the equivalent of 12 × 12 inches is the most convenient dimension. When circular, the bark can be removed, and the tree impregnated by a preservative driven in endwise under pressure.

Bearing Power.—In order to obtain the weight that can safely be borne by the pile, a rule given is as follows: multiply the weight of the ram in cwts. by the height of the fall in inches in making the last blow, and divide the result by eight times the distance in inches the pile is depressed by the last blow. A formula is given for this, as follows:

$SL = RH/8D$.
R = weight of ram (generally about 4 cwts.).
D = distance in inches that pile is driven by last blow of ram.
H = height the ram has fallen in inches.
SL = safe load for pile in cwts.

Another formula for computing the bearing power of piles is known as Wellington's formula, which is as follows:

$$R = \frac{2\,WH}{S + C}.$$

Where R = the safe load in tons.
W = the weight of the monkey in tons.
H = the fall of the monkey in feet.
S = the set under the final blows in inches.
C = A constant ; equals 1 for piles driven by a freely falling monkey ; equals 0·8 for a monkey with a restrained fall, as when driven with a steam winch, and equals 0·1 for steam-driven piles.

A rule of thumb is the following :

When the length of an oak pile does not exceed sixteen times its diameter, it may be loaded permanently with a weight of 450 pounds per square inch of its sectional area.

According to Rankin, a safe load on piles is as follows :

1. In piles driven till they reach firm ground, 1,000 pounds per square inch of area of head.

2. In piles driven in soft ground by friction, 200 pounds per square inch of area of head.

PILING AS APPLIED TO FOUNDATIONS

The following additional information concerning piling as applied to foundations is taken from the paper read before the Liverpool Engineering Society by H. Harrod, B.Sc., A.M.Inst.C.E., A.M.I.Struct.E. :

" The subject of foundation engineering is receiving more and more attention from the engineering profession, and the establishment of chairs of Foundation Engineering in various universities throughout the world is evidence of the great importance which is now attached to this branch.

" Contributory causes, especially in densely populated countries, are the rapidly rising scale of land values, and the immense importance of suitable sites considered from the aspect of economical production and distribution, of cheap power premises in large towns, of centralisation and rapid communication with the nerve centres of commerce.

" The effect is that the sites for buildings are chosen more from the aspect of ultimate commercial economies and convenience than from the suitability of the site from a constructional viewpoint. The problems set for constructional engineers so far as building work is concerned become increasingly difficult.

" In the case of other foundations, such as for bridges, dams, etc., more latitude is allowed, but restrictions are inevitable, and the problem is more or less similar, namely, of constructing foundations capable of supporting a given load, more or less irrespective of the suitability of the site.

" In addition, modern construction tends to a concentrated application of load, and consequently demands a greater bearing capacity from the stratum upon which the structure is founded, or from the substructure.

" The subject is one of vast ramifications, and as it is covered adequately in a general way by numerous textbooks and by descriptive references in

the papers read before the Engineering Associations, it is proposed in this paper to treat of certain modern methods of the preparation of foundations with special reference to the practical aspect.

Geology.—The essential geology of foundation work is mainly the geology of the superficial accumulation of derivative rocks which cover the greater part of the earth's surface. Where bedrock outcrops, or is found at a depth where it can be exposed economically, design and construction are comparatively simple. On the other hand, where considerable thicknesses of the superficial deposits occur the resources and ingenuity of the designer and the constructor are often taxed to the uttermost.

" The deposits have been defined as an unconsolidated heterogeneous aggregate of disintegrated material. They consist of clays, sands, gravels, peats, alluvium, detritus or talus, and ' made ' ground.

" Strata geologically similar will vary in practical or physical characteristics, and any generalisation of these characteristics is manifestly impossible. The main points to be determined about any particular stratum are: (1) bearing capacity; (2) angle of repose; (3) geological incidence, and, in the case of reservoir foundations or dam sites, the degree of resistance to leakage and of permeability.

" ***Proving of Foundations.***—In building work the most satisfactory method of testing the capacity of foundations to carry load is by means of direct loading tests. This, however, is unfortunately not always possible, and the most economical way, especially where foundations are to cover a considerable area, is by means of test boreholes. Too often, however, haphazard methods are adopted for this testing, and the diameter of the test holes is too small to enable enough cores to be recovered to give comprehensive data as to the deposits. This is instanced by the common practice of including borehole results in specifications, but disclaiming any responsibility for their accuracy. It is difficult to conceive a more unsatisfactory state of affairs, and it is believed that the little extra money required for taking accurate bore tests would be amply repaid by enabling engineers and contractors to figure more closely on the cost of projects. In addition, precautions could be taken in advance to deal with possible situations with undoubted ultimate economy.

" The recovery of accurate bore samples is especially valuable where caisson foundations are projected, and much expense can be saved by having the necessary equipment on site for dealing with the conditions revealed. To commence work with inadequate plant, and to hold up construction whilst necessary plant is collected and assembled, is undoubtedly the most expensive method.

" When the nature of the ground on which it is determined to erect a structure has been ascertained, several methods of forming a foundation present themselves. With a medium-weight structure, if the upper ground stratum is of fairly good bearing capacity, it is only necessary to excavate some small way into it and found the footings at that level. If, however, a heavy superstructure is to be erected and ground of poor bearing

quality is present at the surface or overlies one of very poor bearing quality below, or, again, if the nature of the ground varies so that all portions of it are not capable of carrying the same intensity of load, it is necessary to adopt some other method. Two methods are by cementation and by piling, and occasionally by a combination of the two. The application of cementation to foundation problems is one which is of too large a scope to be dealt with within the confines of a paper such as this. It is proposed, therefore, to concentrate in the main on the second alternative, that is, piling.

"The earliest piles were of timber, and timber continued to hold an uninterrupted field until thirty or forty years ago. It is now, however, being rapidly replaced by the newer materials of construction, steel, and concrete, particularly the latter, except for temporary structures, or those in which first cost apart from permanence is an all-deciding factor. These remarks apply particularly to this country; in comparatively undeveloped countries timber is still largely used.

"The purpose of all bearing piles as distinct from sheet piling is to overcome poor surface-ground loading capacities, and to transmit the load from a superstructure to ground strata remote from the surface. A pile performs the function in one of two ways or by a combination of both. It can carry its load by acting purely as a stilt or column, transmitting the entire loading to its toe; conversely it may carry the load along its whole length, leaving little or nothing to be borne by the toe; and thirdly, which is the more usual case, it may transmit the load by a combination of these two methods.

"A point to be borne in mind in designing a piled foundation is that it is bad practice to attempt to divide the total load to be borne by the area between that which normally could be carried by the ground and that which could be carried by the piles. The whole load should be borne by the piles. The reason for this is obvious. With ground consisting of any material except rock, the resistance to a load placed upon the ground surface is not developed until that load has compressed the ground sufficiently to enable it to develop this resistance, *i.e.* some slight initial settlement must take place. If now piles are introduced into the ground and the piles capped by a concrete beam or raft, one of two things must happen:

"(*a*) The piles must carry the load without settlement, so that no loading is applied to the ground surface from the beam or raft.

"(*b*) The whole of the load must first come to the piles, and if in excess of that for which they were designed, they will sink until the beam or raft can settle sufficiently to compress the ground and to develop a resistance equal to its maximum bearing value. This means that some settlement must take place, and means, moreover, that the piles are loaded to their capacity with no factor of safety whatsoever, which is a dangerous state of affairs.

"Recent years have seen a great impetus in the use of piling; it is in many cases the cheapest method of overcoming a foundation difficulty,

and in addition, where the superstructure is to be carried on an area, the bearing capacity of which varies from place to place, it is often the only method of ensuring perfect rigidity and obviating any chance of uneven settlement. The tendency is more and more, in the case of buildings, to concentrate the weight over as small an area as possible, and to concentrate the weight of the building on a number of stanchions, rather than to spread over the whole of the footings, as was the method universally employed before the advent of steel-frame or reinforced-concrete construction. Where rock is met with at or near the surface, the increase in loading is of small account, but if a reliable bearing stratum is not present at or near the surface, piling is then resorted to.

" ***Piling in Groups.***—With piles supported by friction only, the bearing value of the group of piles is not necessarily that of each pile standing alone multiplied by the number of piles. While the driving of piles closely spaced tends in some cases to consolidate the ground, it is necessary to guard against two factors :

" (*a*) The loading intensity due to the sum of the loads on the piles may be too much for the area on which they are driven, giving a tendency for the whole mass to sink relative to the surrounding ground.

" (*b*) Whilst the temporary consolidation of the ground gives a relatively large friction-bearing value to the piles, in the course of time this may be lost, due to the elasticity of the strata. There is a tendency for the ground to recover by losing its compression in an outward direction. This latter tendency can be guarded against by sheet-piling the confines of the area, which is, however, a fairly expensive matter.

" For these reasons, it is not advisable to drive piles at less than 3-foot centres.

" There are three outstanding classes of piling in use :

" (1) The driven pile of timber or reinforced concrete.

" (2) The *in situ* pile, generally of concrete or occasionally of sand with or without a protecting casing.

" (3) The screw pile of iron or steel.

" It is proposed to outline briefly these various types and their applications, and to discuss their relative merits and disadvantages.

" ***The Driven Pile.***—The timber pile needs little or no description ; it can be either a plain tree trunk with the bark removed, as is usually the case in undeveloped countries, or of squared timber in Oregon pine, pitchpine, elm, beech, jarrah, or greenheart ; the two latter are more used in marine work, as being less susceptible to the attacks of the Teredo and the Limnoria. The use of any particular timber is governed by the nature of the subsoil, presence of water, etc., and of course by the cost. No particular precautions in their driving are necessary, except in the case of the last-named, greenheart, which timber, although elastic, is extremely brittle, and it is necessary to guard against the formation of cup shakes under driving. The length of such piles is governed entirely by the type of timber employed, it being remembered that the cheaper

timbers are sawn, one tree yielding, according to its size, a number of baulks, whilst with the harder timbers, jarrah and greenheart, one tree yields only one pile, the trunk being roughly adzed down to size.

"The reinforced-concrete pile is rapidly displacing timber in all but the cheapest work or under exceptional circumstances; properly made, it has an extremely long life and is even cheaper than certain of the timbers. It can be made in cross section and length to any size required, whilst its bearing capacity per square inch of section is greater than that of the timber pile. Reinforced-concrete piles have been constructed up to a length of 100 feet, and lengths of 80 feet are fairly common.

"With these longer piles the main difficulty which arises is that of handling and pitching, it being necessary to avoid over-stressing the pile during this operation. Where the pile has adequate cross section and is proportionately reinforced, it is not difficult to avoid such over-stressing, but where the pile is of necessity slender, extreme care must be taken.

"All driven piles are subject to certain disadvantages. The first one is the difficulty of determining the correct length required; this is often done, where the number of piles warrant it, by driving one or more trial piles about the site, and from the behaviour of these the length required for the remainder is settled. But this, whilst the best method available, is by no means satisfactory. It is rarely that the remaining piles drive to the same length as the trial pile. The author has knowledge of one particular contract where three trial piles were driven, each of them resulting in a fairly consistent length. The remaining piles were cast on this basis, and on being driven, in each case far exceeded the depth that was expected. It was found that each of the three piles had struck a fair-sized boulder at about the same depth; this is, of course, an extreme case, but it is illustrative of what may happen.

"Should a reinforced-concrete pile on driving have to be either cut off or lengthened, it becomes an expensive matter, particularly in the latter case, where it involves stripping the pile head, casting in position an additional length of pile, and bringing back the pile frame, to redrive when matured. It causes, moreover, a loss of time, which is a twofold disadvantage, since as the piling is the first part of the work, both this and the constructional work which is to follow are retarded.

"With both timber and concrete piles the chief asset claimed is that the piles may be examined before driving; it is not too much to say that this asset, except in the case of easy driving, is particularly valueless. With hard driving it is impossible to dogmatise on the state of the pile below ground. In the case of timber, although driven to the required set, the pile may be buckled, turned up, or shredded. An indication that this state of affairs is on the point of being realised is given during the driving when the hammer dances on the head of the pile without appreciable penetration. To continue driving under such circumstances is almost certain to damage the pile below ground, if not at the head. At this point it is advisable to mention that with all pile driving the heavier the hammer

relative to the weight of the pile, the better the result. A pushing action rather than a percussive one is the ideal. This is particularly the case with reinforced concrete, where a heavy hammer with a short drop is preferable. It is not advisable to adhere to the same drop throughout the driving of the pile, and an experienced piling foreman will vary the drop according to the way the pile is going; coaxing the pile with a short drop through difficult strata and opening up with a longer drop when the pile is freely moving.

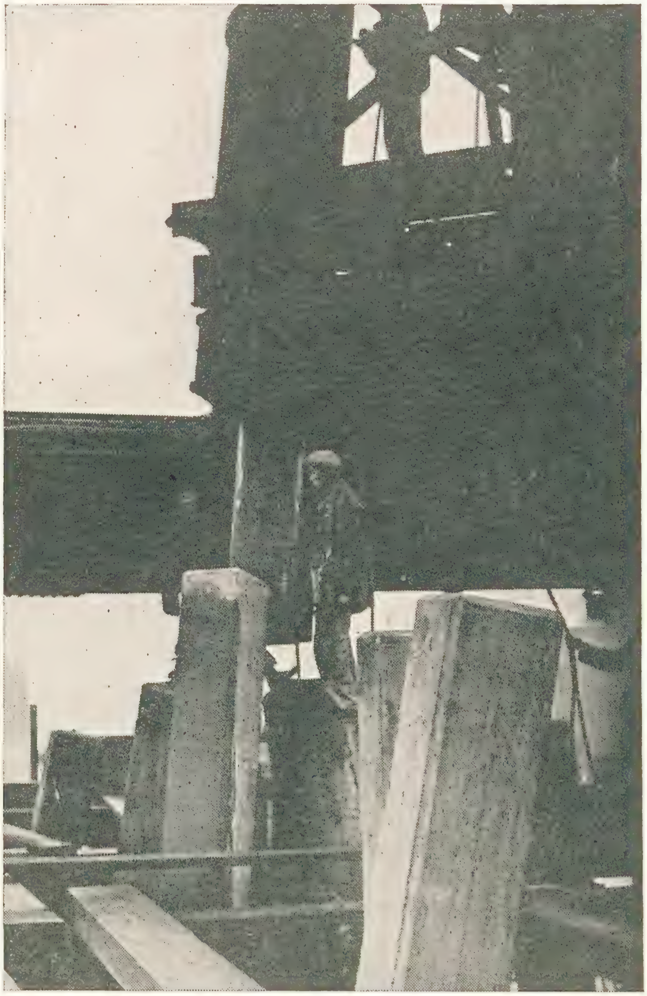


Fig. 94.—Pile driving—the piles are of Stent pre-cast concrete.

(By courtesy of Stent Pre-cast Concrete Ltd.)

"A piling chart is often compiled, plotting the number of blows against the penetration of the toe. While this is useful in fairly easy ground, where a uniform drop is used, in ground of varying nature, where it is necessary to vary the drop according to the strata passed through, it cannot be done with the same exactness. It is sometimes attempted by arithmetically proportioning the penetration per blow according to the drop, bringing the results down to a uniform drop. This, however, does not give an accurate picture of the pile-driving operations, since the energy of the blow is absorbed in a different manner with the short drop from that of a long drop.

"In pile driving the choice of three types of hammer is available:

"(*a*) The drop hammer of a weight usually up to 6 tons.

"(*b*) The single-acting steam automatic type up to 4 tons.

"(*c*) The double-acting hammer.

"The latter is rarely employed on bearing piles such as those treated here. It finds its chief application in the driving of steel-sheet piling. Its principle is to deliver a comparatively large number of blows of small

energy, thus keeping the pile in a state of vibration and overcoming ground resistance in this manner. It is used at times in driving timber or concrete bearing piles, but it is not so successful as type (*a*) or (*b*). Its chief drawback is that with a heavy pile the inertia of the pile tends to absorb the blows of the hammer. Piles have been driven to a set with this type of hammer, and on then being treated with either type (*a*) or (*b*), particularly the former, *i.e.* the gravity drop hammer, have gone down at a rapid rate.

Fig. 95.—Pile driving—the piles are of Stent pre-cast concrete.

(By courtesy of Stent Pre-cast Concrete Ltd.)

"As an example the following results were obtained in the driving of a 36-foot timber pile 12 × 12-inch section:

"Using a No. 6 McKiernan-Terry double-acting hammer with boiler pressure 70 pounds per square inch, the first 45 minutes resulted in 6 feet 9 inches penetration; the next 45 minutes in 1 foot 11 inches, and the next 45 minutes in 10 inches only. As at this stage the pile was not moving the hammer was taken off, and a drop hammer of 10 cwts. with a 7-foot drop was tried. Under this the pile commenced moving slowly, going down a considerable depth and finishing at $3\frac{1}{2}$ inches in ten blows.

"Type (*a*) is the hammer in most general use, and is usually driven with a friction winch.

"Type (*b*) is also in frequent use. It can deliver more rapid blows than type (*a*), and the drop can be governed more accurately. It is, however, more expensive in steam, and the efficiency of the blow is hardly so good as that of type (*a*).

"With the reinforced-concrete pile, particularly a long slender one

crushing at the toe, fractures along its length caused by excessive bending, due to weakness of strata or deflection of the toe, or even a complete shear across the cross section, may occur, with the result that in some cases the upper portion of the pile remains vertical and descends past and parallel to the lower portion.

"A point of interest arises in the design of the toe of a reinforced-concrete pile. It would appear that the more acute the angle of the toe, the easier would be the driving. This, however, as a general theorem, is not borne out in practice. Other things being equal, the blunter the toe the better the pile. This is particularly so where a pile is driven through soft material until it reaches rock, *i.e.* where the stilt action is uppermost. In such cases, most of the load is transmitted through the pile to the toe, and here the larger the cross section of the pile the better. It will be appreciated that if a 14 × 14-inch reinforced-concrete pile is carrying, say, 50 tons load under these circumstances, the intensity of stress on the concrete at the foot of the pile in the case of a long slender shoe of 22° angle is beyond that which it can stand. What happens then is that the concrete above the pile shoe crumples up. In such circumstances, where it is imagined that the pile has penetrated the rock for, say, 12 inches or so, it is probably the case that the lower 12 inches of the pile has given way. In tough homogeneous ground it is probably true to say that the more acute the angle of the toe the easier would be the driving, but in most other cases it is found that the shape of the toe or shoe has little effect upon the driving, and that in fact a perfectly blunt square-ended pile will drive into certain ground with no more effort than is required with the long pointed shoe. The reason for this is not obvious; it is thought that the action of the blunt end is that the pile toe tends to tear open the strata through which it passes, opening out a hole larger than the diameter of the pile. Thus, although the actual resistance to penetration of the toe is greater, it is compensated by the reduction in surface friction between the shafts of the pile and the surrounding ground during its descent.

"A further trouble occurring in the driving of slender piles is that due to whip and vibration along the length of the pile. Recently, in the driving of a number of reinforced-concrete piles 14 × 14-inch section and 70 feet to 75 feet in length, this fact was experienced by the author in a very marked manner. These piles were driven with a 4-ton drop hammer operated by a friction winch through ground consisting in the lower measures of packed sand and water overlaid by a more consolidated material. During driving the heads of the piles repeatedly shattered, although well protected by the helmet and pads in the usual manner. On the assumption that the concrete of which the piles were composed was in itself at fault, special heads were cast on the piles, using aluminous cement and granite chippings. No improvement resulted from this. Test cubes were made on the site from the actual batches taken from the

mixer and as placed in the piles, and further laboratory samples, using the same material and water content, were made up. Under test both sets of cubes gave remarkable agreement, showing that the concrete was not at fault. The author is of the opinion that this phenomenon is entirely due to the vibration and whip caused by the lower portion of the pile being firmly embedded in a tough stratum with the upper portions comparatively free in weaker strata. The piles are excessively slender, and each hammer blow tends to cause momentary bending. As the hammer is lifted after each blow the head whips across and is vibrating as the next blow catches it. This next blow partially damps out the first vibration and imposes a further one. Under this action disintegration rapidly sets in, the concrete spalling not only at the head, but at points lower down the pile. With these particular piles it was found that the only method of getting them down to the required depth was by water jetting used in conjunction with hammer blows of small drop.

"A point to be watched in such driving arises when the head of the pile is shattered and a new length has to be cast on preparatory to redriving. The ground, during the few days which elapse before redriving is possible, takes up an extremely tenacious grip on the pile, and if care is not taken the hard driving necessary to restart the pile causes a further fracture before the pile again begins to travel.

"A further disadvantage applicable to pre-cast reinforced-concrete piles is the waste period which elapses in casting and maturing the pile before it can be handled and driven. With ordinary Portland cement this period varies from four to six weeks, but with rapid-hardening cement it can be lessened to a minimum under the most favourable circumstances of four or five days. With an aluminous cement two days suffice, but the increased cost of this cement over the Portland cement renders its use as a rule undesirable.

"The last main disadvantage attached to the use of reinforced-concrete piles is that the reinforcement must of necessity be designed sufficiently heavy to withstand both handling and driving stresses, which are often in excess of those arising when the pile is performing its normal function in the ground.

"It sometimes happens in the design of a foundation that the question of uplift has to be considered, as for example in the case of a tall water tower or the larger of the pylons which are now being erected under the grid scheme. To resist this uplift or overturning would be an expensive matter in some cases if only dead weight, in thickening and deepening the foundations, were to be employed, and piling is resorted to, the piles being used as anchors or dowels. To give sufficient resistance to withdrawal, the piles are sometimes driven at a rake, but more generally are vertical. The average pile, after being driven and allowed to rest for a fair period, has a remarkable resistance against withdrawal, as will be evidenced in the following examples: 18-inch square piles driven into chalk a depth of 5 feet have required a total uplift of 45 tons before

they could be freed. Again, 15-inch octagonal piles driven 20 feet into ground composed of filling, sand, and clay, have required 100 tons each for extraction. 12 × 12-inch and 13 × 13-inch piles driven from 30 feet to 35 feet in silt and sand took 55 tons each average, and 14 × 14-inch timber piles driven 12 feet to 15 feet in sand and gravel required 35 tons to 55 tons. It will be seen that there is a fairly high surface friction between the piles and the ground, and that in most cases a plain pile will suffice. Attempts have been made to increase the anchorage power of piles by casting on to them a blob if of reinforced concrete or by bolting on chogs if of timber. Such additions, however, are not necessarily advantageous, except in soft grounds, since they tend to weaken the strata too much immediately round the pile and thus destroy part of the surface friction from the pile shaft in the ground.

"*The 'In Situ' Pile.*—Numerous types of this class of pile have been evolved, many of which have proved impracticable. There is still, however, a wide choice of type in the employment of such a pile. This class of pile can be divided into two main groups—the unprotected, and the shelled or protected. The principle is generally the same, in that a sealed tube is driven into the ground to the required depth, the tube filled with concrete, and reinforcement inserted if required. The tube is then extracted in the case of the unprotected pile. Further variations are in the formation of a bulb at the foot of the pile, and in the expansion of the diameter of the pile along its length. These expansions are obtained generally by mechanical ramming, or occasionally by the use of explosives. They all require a fairly heavy headgear of piling frame, an inconvenience to piling generally, since this necessitates a considerable amount of head room, with heavy transport and erection costs, and difficulty of moving about an uneven site.

"These difficulties can be got over by sinking the pile by boring instead of driving. Boring has a further advantage, which is a very important one where the work is to be carried out in the close vicinity of existing buildings, in the almost entire absence of vibration and ground displacement. There is a large field of use for the bored type of pile, since at the present day an ever-increasing number of buildings are being demolished to make room for larger and heavier structures, such sites being invariably surrounded by existing buildings.

"An interesting development of this latter type of pile is the François cementation pile, where the boring is filled with dry gravel, tamped as required, and the mass injected with cement under pressure, this keying firmly into the ground along the whole pile length. Reinforcement can be added to such a pile as required. Cementation is also applied to certain grounds as an adjunct to the use of piling, where it is not desired to sink piles to any great depth. Certain strata, such as ballast, gravel, or sand, etc., can be injected with cement to form an underground bed or raft of concrete, on which the piles can be founded.

"All types of *in situ* piles possess certain advantages over the driven

pile, chief among which is the fact that the exact length of pile required at any particular place is formed with no wastage due to cut-off lengths, or expense and delay due to the necessity of lengthening. Further, a much-increased speed is gained, since no time is lost in casting and maturing the piles or in handling and pitching. (It should be appreciated that with a driven pile, unless the driving is extremely hard, the majority of the time occupied in piling operations is that due to handling and pitching the pile, the actual driving occupying a comparatively small length of time.) A lighter reinforcement is also possible, and a weaker mix of concrete can be used without impairing the load-carrying capacity. With the bored pile, moreover, a core of ground is extracted with each pile, so that no doubt exists as to the nature of the subsoil. The employment of the bored pile, therefore, does away with any necessity for trial borings, except to indicate the probable length of the piles with a view to a preliminary estimate of cost.

"Of the two main types of *in situ* pile, the 'unprotected' one suffers certain disadvantages as compared with the driven pile, which disadvantages are non-existent with the protected type. With the unshelled type one cannot be certain that the pile column below ground is not injured. In water-charged ground there is a possibility of loss of cement, particularly where the ground water is in motion. In chemically charged ground a deleterious action may take place between the cement and the chemicals, and in certain types of ground elastic deformation of the pile shaft may occur, due to the diminution of cross section. This is the more likely to occur where piles are driven in closely placed groups.

"It would appear, therefore, that the ideal pile for all ground conditions is the protected one. The protection usually consists of a steel or concrete shell, which is driven into the ground and left behind. After driving, the shell, which should be watertight, can be inspected from top to bottom, thus giving the absolute guarantee of protection. Such a pile is by nature of its construction generally more expensive than the unprotected one or the solid type, but in most circumstances this expense is more than warranted by the certainty which exists as to the soundness of the pile."

THE OPERATION OF PILE DRIVING

Pile driving in its most elementary form is merely the hammering with a mallet of pieces of timber endwise into the earth.

For convenience in handling large timbers the mallet is replaced by a simple form of machinery, which consists of a weight and a tackle and winch for raising the weight to a certain height, at which it is set free and falls vertically on to the head of the pile held in position to receive it in just the same way as the mallet strikes the timber as mentioned above. The weight is termed the *Monkey*, which consists of a block of iron weighing from 5 cwts. to 40 cwts. This is raised by a winch known as a crab, which may be worked either by hand or by steam, and in the most

recent forms by electricity. The winch raises the weight vertically in a track consisting of 6 × 6-inch guides supported by braced shores and held vertical by guides to a given height. At this height the weight or monkey is released, when it descends by the force of gravity on to the head of the pile. The distance which the monkey is raised is generally about 5 feet, but a point that should be noted here is, that practice has proved that it is better to use a heavy monkey with as short a fall as possible, than a light monkey with a long fall. The action of the slip hook is automatic, and is so set that when the monkey reaches the desired height it is freed from support and so allowed to fall. The guides in which the monkey works should be faced with iron to resist wear, and the whole triangular framework which holds the guides in position should be mounted on weighted sleepers to prevent any sinking into the earth. In more elementary forms of pile-driving machinery a cord is fixed to release the slip hook.

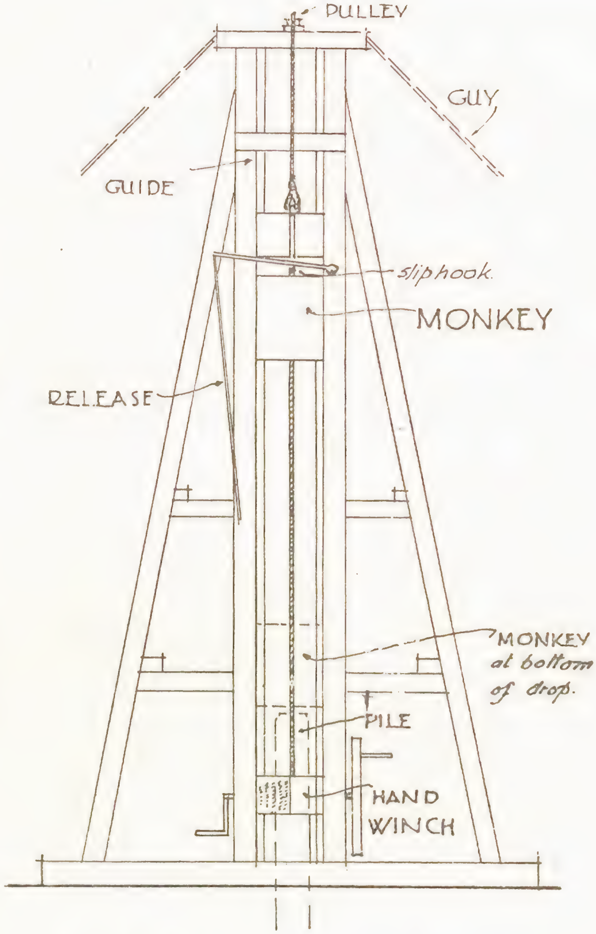


Fig. 96.—Hand-driven pile-driving machine.

Consequently, it will be easily understood from the foregoing that the supporting power of a pile, that is, the resistance it offers to any weight imposed upon it, bears a relation to the distance which this pile sinks in the ground when it is struck by the monkey, and the formulæ which have been given above are in fact nothing more than the mathematical relationship of these factors. The supporting power of a pile depends upon three things :

1. The resistance at its point offered by the soil into which it is being forced.
2. The frictional resistance of the earth at the sides of the pile ; and
3. The strength of the pile itself.

A simple formula, given by Major Saunders, will be easily understood

if these points are held in mind. The safe load in cwts. to be imposed upon a pile equals $\frac{Wh}{8d}$,

Where d = the distance driven by the last blow in inches.
h = height fallen by monkey in inches.
W = weight of monkey in cwts.

The Pile.—The actual pile, whether circular or square, is fitted at the top with a circular iron ring to prevent its splitting under the blows from the monkey. The feet are also shod with cast-iron points, which increase the penetrative capacity of the pile, and at the same time prevent its splitting when stony ground is encountered (see Fig. 93).

SHEET PILES

Sheet piles consist of flat timbers or steel sections from 9 inches to 11 inches wide and from $2\frac{1}{2}$ inches to 4 inches thick. For steel sheet piling see page 145. Sheet piling is used to prevent lateral movement of soil, as in loose sand. In conjunction with sheet piling when used for enclosing a site for building upon, guides must be driven in at distances from 6 feet to 10 feet apart. These are timbers 9 inches square, pointed and shod in a similar manner to piles. The top must also be fitted with a wrought-iron ring. The head of the pile is driven in to within 2 feet of the ground, and they are then connected together horizontally by 9 × 6-inch timbers bolted to them in pairs, a space being left between them in which to fit the sheet piles.

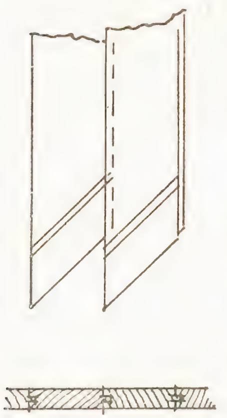


Fig. 97.—Sheet piles, wood.

Sheet piles may be jointed together, where something more permanent is required than the ordinary butt joint supplies, by tongued and grooved joints, or they may be bird's-mouthed together. In conjunction with the use of sheet piles, ordinary piles may be driven in within the enclosure to further consolidate the ground, and lines of ordinary piling will be driven under the foundations of the proposed building.

CLUSTERED PILES

Clustered piles are used where it is desired to penetrate through a hard stratum to a soft soil beneath. The method of constructing clustered pile systems is to drive the piles in to a depth of the level of the concrete foundations, and to fix over their heads, in double rows, longitudinal members. The concrete is then laid in over these members, and in between them in such a manner as to afford the concrete a key over these members.

OTHER FORMS OF PILE-DRIVING PLANTS

These are hammers worked by steam, and a water-jet method. The McKiernan-Terry pile hammer is a double-acting hammer originally used in driving light-wood sheeting, but the advent of steel-sheet piling gave rise to a demand for a more powerful apparatus (Fig. 98). This led to the designing of a machine having a complete range of hammers, calculated to perform every kind of driving required in the latest developments of piling.

The Double-acting Hammer actuates by a rapid succession of blows, thus keeping the pile in practically constant motion. It consists of only two moving parts, which are entirely enclosed, and it can be driven by steam or compressed air. The blow of the hammer is delivered directly upon an anvil block, which rests on the head of the pile, thus evenly distributing its force and preventing damage to the pile itself. The action is similar to that of the pneumatic chipper, wherein the head of the chisel is never burred over or damaged, because the blow is always struck in the same place. These hammers may be suspended from a crane, derrick, or pole, in such positions as where it is inconvenient to use a frame, and owing to the small head room required they may be used in cramped situations. When inverted, the hammers can also be used for withdrawing the piles. When driving, the full weight of the hammer should rest upon the pile; the hammer line should be just taut when operating without guides or leaders, but should be quite slack when the hammer is supported in leaders; bolts should always be kept tight, and the pile hammer should not be allowed to work or run unless it is resting or bearing its full weight on the pile.

As is the case with all machinery, lubrication must be given the strictest attention, and it is recommended that on starting the hammer when cold the steam should be turned on and off several times. This will have the effect of warming up the hammer and expelling any water there may be in the cylinder.

Again, as with all pile driving, it is useless to continue driving when there is no further movement of the pile, as this only causes destruction to the pile and unnecessary wear on the hammer. This mistake is more likely to be made with a hammer working in this manner than one of less rapid operation. Consequently also a careful watch must be kept on the pile during driving.

Where there is any irregularity in the operation of the hammer, this may be caused by a foreign matter in the ports of the valve chest. The valve should then be removed and any matter cleared away from large and small ports. As it is essential that the steam should be as dry as possible, the steam lines should be kept short. In cold weather, and where there is any sign of a water knock, there should be provided suitable drainage at the hammer. The hose should be blown out before attaching it to the inlet of the hammer.

Single-acting Pile Hammers.—In a single-acting pile hammer worked

by steam or air, the cylinder delivers the blow instead of the piston. The force of the blow is occasioned by the weight of the falling cylinder and the distance through which it falls, the steam or air providing only the upward motion, whereas in the automatic hammers the piston is not only raised by the motive fluid, but is also forced down by it, and the force of its blow is due to the weight of the piston plus the pressure behind it. The difference between the effect of these two blows is that whilst those of the automatic hammer are a series delivered at a high velocity, that of the single hammer is of a crushing nature. The number of the foot-pounds exerted by the single-acting hammer at each blow is greater than the double-acting hammer of the same size, though the latter, owing to the larger number of blows given during the same period, actually exerts more energy. The single-acting hammer requires an operator to admit the steam or air.

For the driving of steel-sheet piling, timber-sheet timber piling up to moderate sectional area and penetration, and concrete piles of the smaller type, the double-acting hammer will be found the most efficient, but for large concrete piles, or for timber piles of a large sectional area, driven through difficult soil, the single-acting hammer will provide the best results. The reason underlying this is that with the lighter hammer the blows, although delivered in rapid succession, are absorbed in the pile and are individually insufficient to overcome its inertia and the resistance of the soil. For example, a concrete pile 16 × 16 inches and 50 feet long, struck by a double-acting hammer of, say, 2 tons, would be shattered when the pile entered stony ground, whereas the single-acting hammer would drive it intact to the required level.

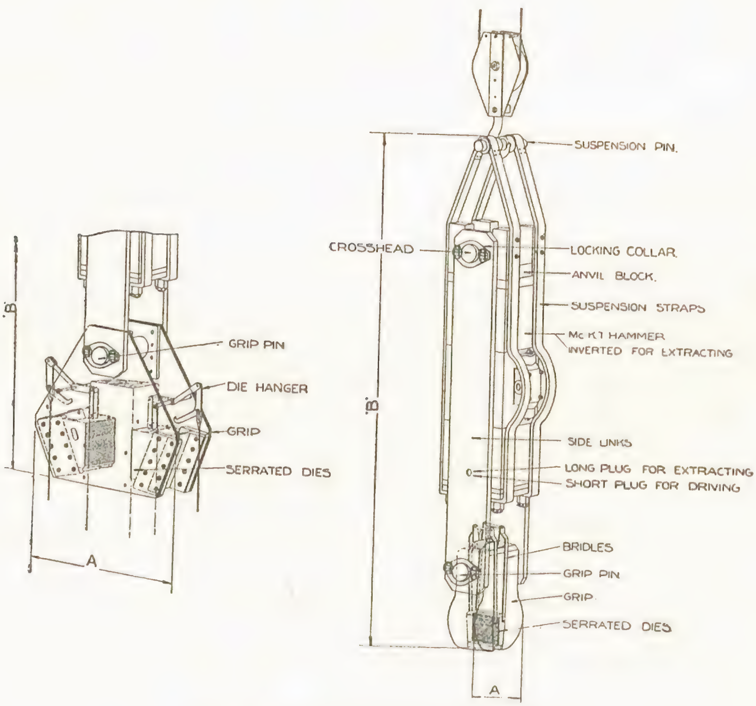


Fig. 98.—McKiernan-Terry hammer.

EXTRACTION OF PILES

The theory underlying the efficient extraction of piles is the setting up of a vibra-

tion throughout the full length of the pile to be extracted. This overcomes the frictional resistance of the surface of the pile against the soil at the same time as there is being exerted an outward pull.

In this the McKiernan-Terry hammer is found most serviceable, in that it gives a great number of blows per minute, and the hammer used inverted and fitted with a special strap attachment gives satisfactory results in extracting piles.

FRICTION STEAM WINCHES

For use with pile-driving hammers steam winches are now supplied.

The Zenith, manufactured by the British Steel Piling Co., Ltd., is a high-class winch, useful also for haulage, logging, cableways, derricks, loading, and well sinking. It can be driven by steam, petrol, compressed air, or electricity. Every boiler is tested to within double its load, and all its operations are within easy control of a driver, who has an unobstructed view. The barrels are of cast iron, brass bushed, and run loose on the barrel shafts. The female end of the clutch is cast *en bloc* with the barrel carefully machined and having a break recess on the outside and the ratchet and fall at the opposite end. The clutch, which is of the V type, is operated by forcing the female end of the barrel on to the projecting end of the spur wheel. The movement is effected by means of a triple-threaded screw of mild steel working in a gunmetal nut, secured to the frame side and controlled by a small lever. This lever pushes a rod inserted in the barrel shaft attached to the cross bar, and the latter forces the barrel along the shaft, thus enabling the clutch to engage.

A ball-thrust washer is placed between the end of the screw and the rod passing through the barrel shaft, and all the thrusts are taken up by means of ball-thrust washers. The whole works in a gunmetal oil bath, ensuring perfect lubrication to all parts. A spiral spring forces the barrel clear of the clutch when the pressure is released.

When the winch is in operation, the clutch levers are pushed forward towards the boiler. When they are out of action, they are pulled in the opposite direction away from the boiler.

STEEL-SHEET PILING

Developments in the use of pile driving have shown the necessity for a more adaptable,

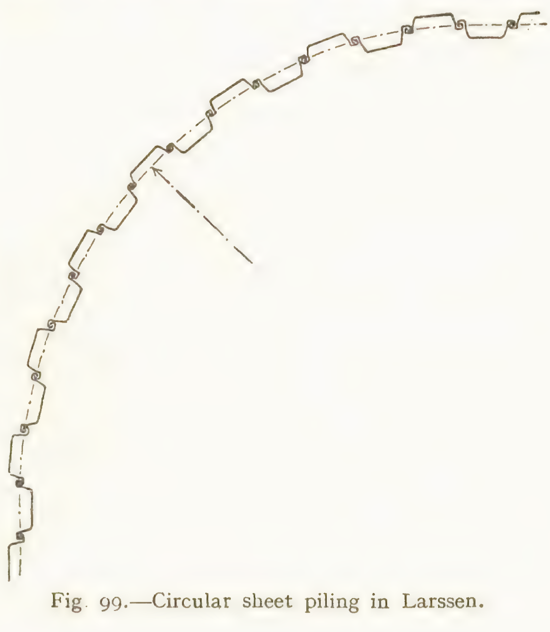


Fig. 99.—Circular sheet piling in Larssen.

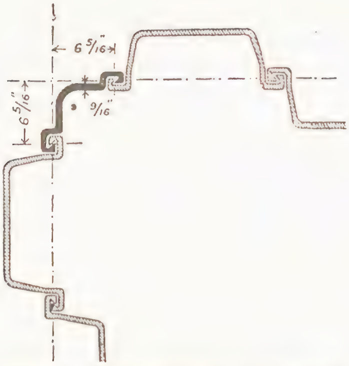


Fig. 100.—Left-hand or open corner.

durable, and stronger material; and to meet these requirements, sheet piling of steel has been designed, that provided by the British Steel Piling Co., Ltd., being amongst the best known.

Steel-sheet piling consists of trough-shaped sections having an interlock, located on the neutral axis where the stresses are least, so that the piling can be driven and withdrawn with equal ease and without risk of distortion.

Another form of steel piling is that known as the Universal Joist Piling. This consists of rolled-steel joists, connected by separate interlocking clutches, and in this also the interlock is located on the neutral axis where the stresses are least.

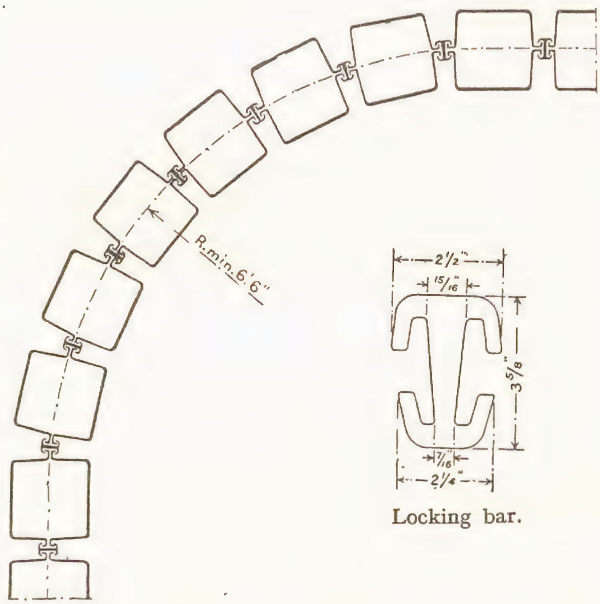


Fig. 101.—Circular sheet piling in box.

Steel-sheet piling can be obtained, if required for special situations, in lengths up to nearly 100 feet, and it is also possible now to cut the piles off under the water at almost any depth by means of a special oxy-hydrogen submarine cutting plant. For piles exposed to the action of sea water, steel containing a small proportion of copper is used, the addition of the copper having a rust-resisting action. Portions of steel piling permanently under the water are not subject to corrosion, and below the ground level only a slight coating of rust forms, which combines with silicic acid and thus provides its own protection.

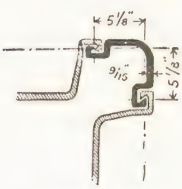


Fig. 102.—Right-hand or closed corner.

For driving the steel-sheet piling it is found more economical to interlock the piles in pairs and drive two at a time. A steam- or air-driven double-acting hammer is advised, as the best results are to be obtained from a hammer giving rapid blows with a short stroke.

This steel-sheet piling is also designed for the purpose of constructing permanent retaining walls, and is capable of withstanding high pressures.

The interlock consists of a dovetail joint making contact at three surfaces. The clearance is small, yet the sections are so accurately rolled and straightened that they are easily joined and driven in. They become

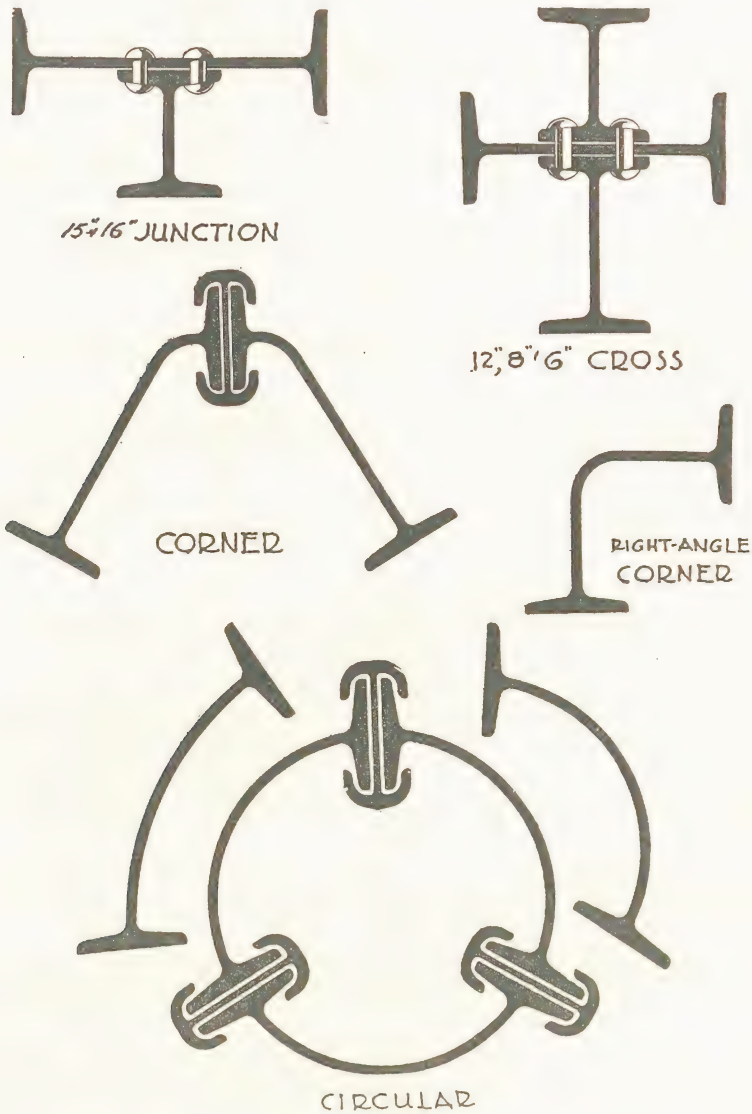


Fig. 103.—Larssen section junction, and corners.

watertight without the use of any packing, as the mud and silt contained in the water which trickles through at the commencement in a short time seals the joints.

The following strengths are obtainable :

1. Ultimate strength, 28 tons per square inch, with an elongation of 22 per cent. on 8 inches.

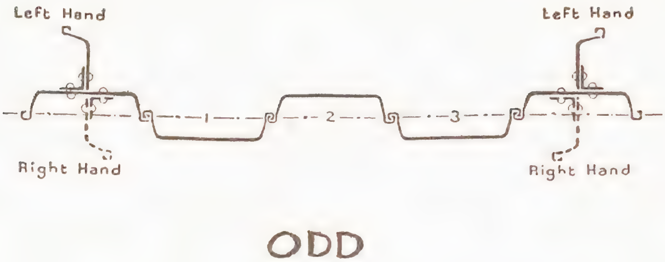


Fig. 104.—Larssen junction piles—Universal Specials.

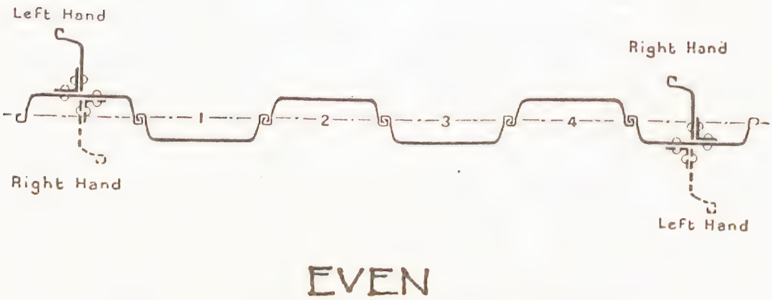


Fig. 105.—Larssen junction piles—Universal Specials.

2. Ultimate strength, 28 to 33 tons per square inch, with an elongation of 20 per cent. on 8 inches.

3. Ultimate strength 33 to 38 tons per square inch, with an elongation of 18 per cent. on 8 inches.

For greater strength Larssens Sheet Piling is supplied in box sections, each section being $18\frac{1}{8}$ inches wide, the joint being effected by a clutch. This piling may also be used in the construction of circular structures with a locking bar specially designed, having an external dimension of $2\frac{1}{2}$ inches and an internal dimension of $2\frac{1}{4}$ inches. For junctions at right angles, a rolled corner is provided.

The Universal Joist Steel-sheet Piling consists of joists, ranging from 15 × 5 inches to 6 × 5 inches, connected by a specially designed clutch, which fits over the flanges of the joists. There is a clearance between the joist and clutch to allow of easy driving, but the joint is perfectly watertight without corking of any kind. However, should there be any leakage, ashes thrown into the water will be drawn into and stop the leaky places.

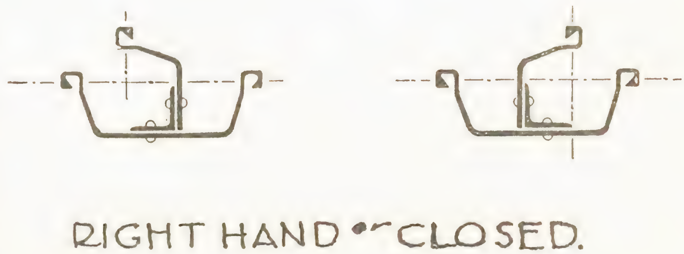


Fig. 106.—Larssen junction piles—Universal Specials.

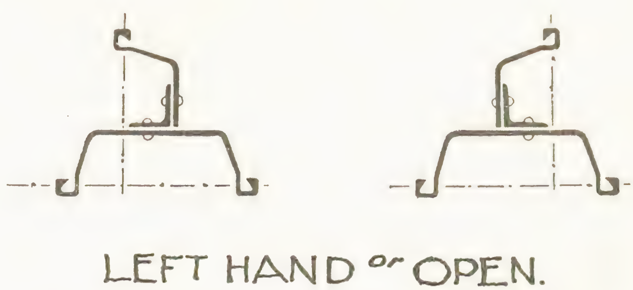


Fig. 107.—Larssen junction piles—Universal Specials.

Corner piles can be obtained to any angle required, and junctions or crosses are formed by riveting other joists on one side or both sides of the pile. When it is required to drive the piles in short lengths only, fish-

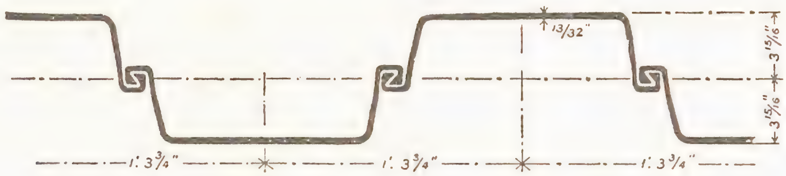


Fig. 108.—Larssen steel-sheet piling.

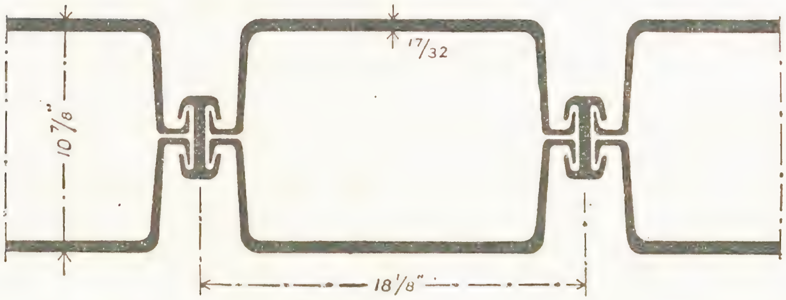


Fig. 109.—Box pile.

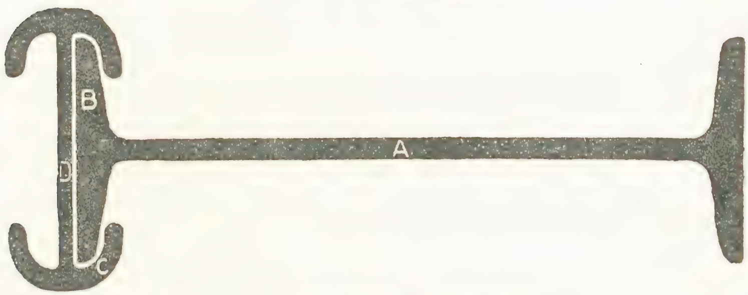


Fig. 110.—Universal joist steel-sheet pile.

plates are provided. The joints are usually staggered by one or two feet; the bolts being provided with square necks and the outer fishplates with square holes, the unscrewing of the nuts is made easier.

CONCRETE PILES

A form of concrete pile known as the Simplex Concrete Pile is installed in the following manner. A cast-iron shoe is placed on the ground in the position where the pile is required to be driven. A hollow steel tube, usually 16 inches in diameter, called the driving form, held in a vertical position in the piling machine, is lowered until the lowered end rests on the pile shoe. The form is then driven into the ground by means of a drop hammer, usually 2 tons in weight. The hammer and drive cap is

then raised out of the way of the top of the frame, and the steel reinforcing cage is lowered into a central position inside the form. Freshly mixed concrete is then poured into the form until the latter is filled to the level required for the top of the completed pile. Extracting gear is then fixed to the top of the form, which is slowly withdrawn.

During the process of withdrawal, the concrete issues from the lower end of the form and, being driven downwards and outwards by its own weight, it completely fills the hole made by the form, running into any voids in the sides of the circular hole, such as may have been occasioned by the displacement of stones during the driving operation. It should be noted that the weight of concrete in a pile 23 feet long is 2 tons, which, combined with its plastic condition, causes it to force itself into all voids. During the process of setting, the concrete becomes cemented into the surrounding soil, thus providing a skin friction.

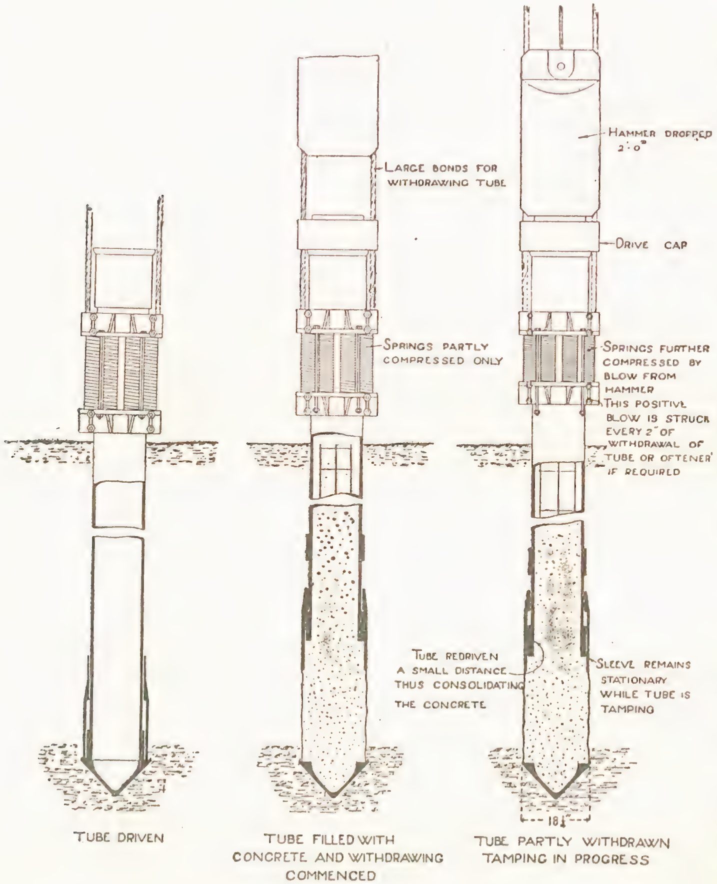


Fig. 111.—Method of installing "Tamped" Simplex Concrete Pile.

A development of the Simplex Concrete Pile is that known as the Tamped Pile. The method is the same as that used with the Simplex Pile until the form is ready to be withdrawn. When the concrete has been placed up to the required level, a hammer and drive cap are lowered into position on to the top of the form, and the withdrawal begins. At every 2 or 3 inches of withdrawal, the hammer strikes a blow, causing a downward movement of the form. This movement rams the concrete against the inside of the patent sliding sleeve at the foot of the form, forcing the concrete out at the bottom from this sleeve.

A further modification of this concrete pile is that for use when driving

through exceptionally hard strata. The driving form is fitted with an alligator jaw point instead of the ordinary type of cast-iron pile shoe. The jaws are closed before the form is lowered to the position on the ground. When the form has been driven and the concrete placed, withdrawal begins, and the weight of the concrete causes the jaws to open to the full width of the form and allows the concrete to pass freely through it (Fig. 113).

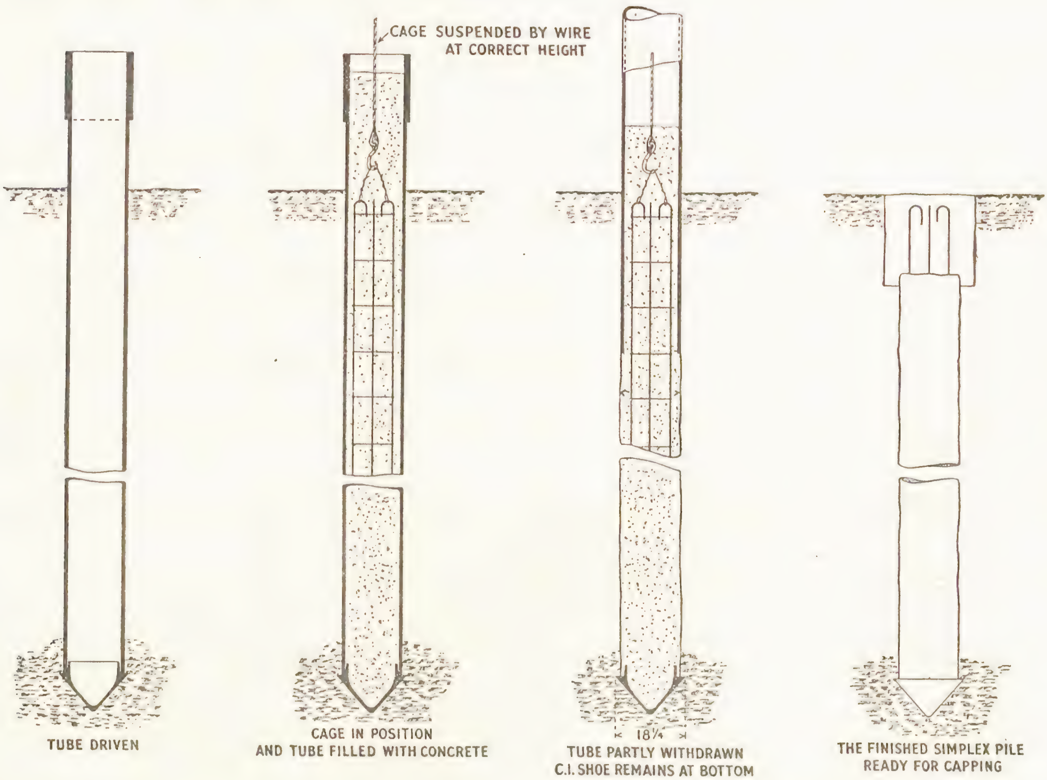


DIAGRAM SHOWING METHOD OF INSTALLING SIMPLEX CONCRETE PILES

Fig. 112.

Vibro Concrete Piles.—Another system of driving concrete piles is that known as the Vibro, as carried out by the British Steel Piling Co., Ltd. The steps in the formation of this pile are as follows: a 16-inch diameter piling tube fitted with a cast-iron shoe is driven to the required penetration by a special piling hammer; after the tube is driven, it is filled with concrete, and the tube is then extracted, the extraction of the tube and the formation of the pile being effected at the same time by the upward and downward percussive blows of the steam hammer.

At the end of an upward blow delivered by the hammer, a layer of concrete having been deposited from the end of the tube, the tube has risen a small distance, and the efficient depositing of the concrete is en-

sured by the great upward acceleration imparted to this tube by the hammer, and the friction of the concrete on the walls of the tube is thus overcome. The tube at the end of its downward travel, caused by a light cushion blow from the hammer, causes the concrete to move downwards with the tube as a solid ram, giving a considerable tamping pressure over the whole section of the pile. During this operation, the

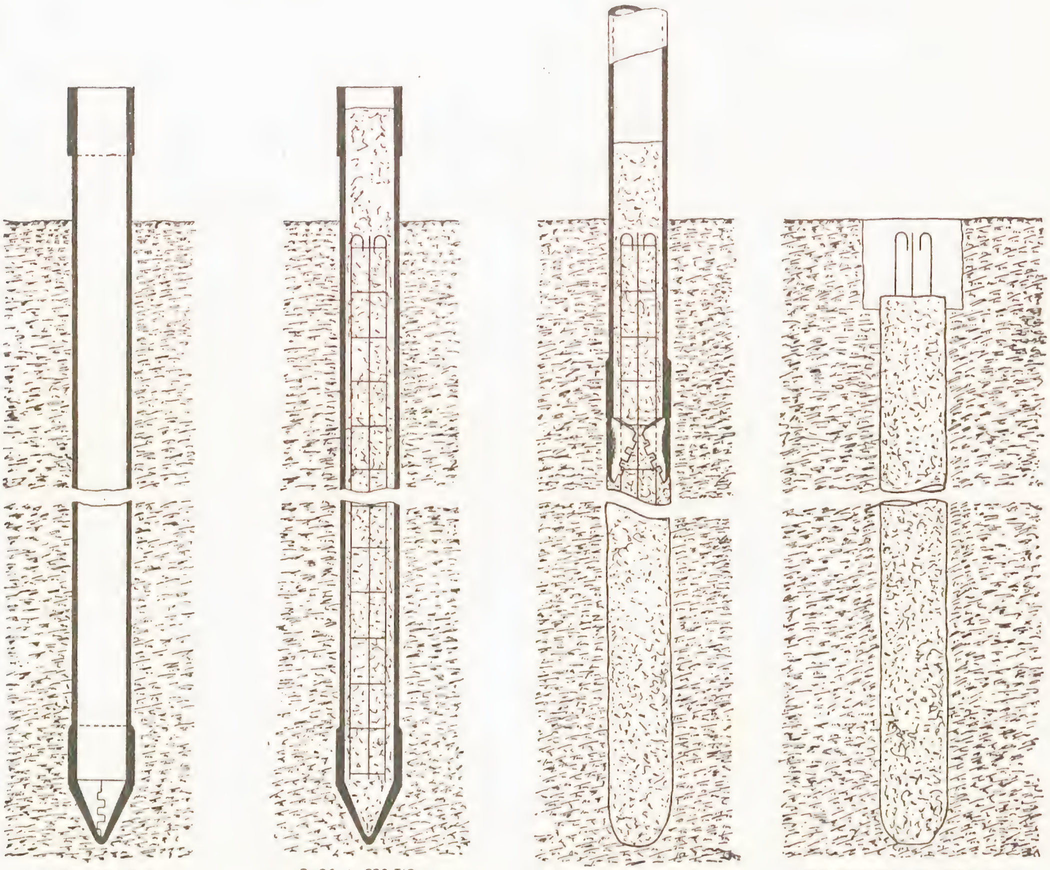


Fig. 113.—Method of installing Simplex Concrete Piles with alligator point.

layer of concrete previously deposited is compacted and rammed outwards to fill the space left by the tube, whilst a corrugated surface is formed on the pile, which gives it an excellent frictional grip on the surrounding ground.

This cycle of upward and downward blows is continued at the rate of 90 times per minute, a net upwards displacement of the tube being produced by each cycle of blows. The completed pile has a diameter of 17 inches, and the top may be finished off at any desired level below the

ground according to the amount of concrete poured into the tube. This pile may be reinforced with any specified cage of reinforcement, the normal reinforcement for 50-ton loads in medium ground being four $\frac{3}{4}$-inch diameter bars with $\frac{1}{4}$-inch diameter stirrups every 9 inches.

THE PATENT PRESSURE PILES

With the growing use of other materials for piling than wood—and to an extent it was the case with wood—the problem of vibration caused in driving has become a cause for anxiety. Especially is this the case with concrete piles. To overcome this difficulty a special pile formed *in situ* by air pressure and without vibration has now been put on the market by the Pressure Piling Co., Ltd.

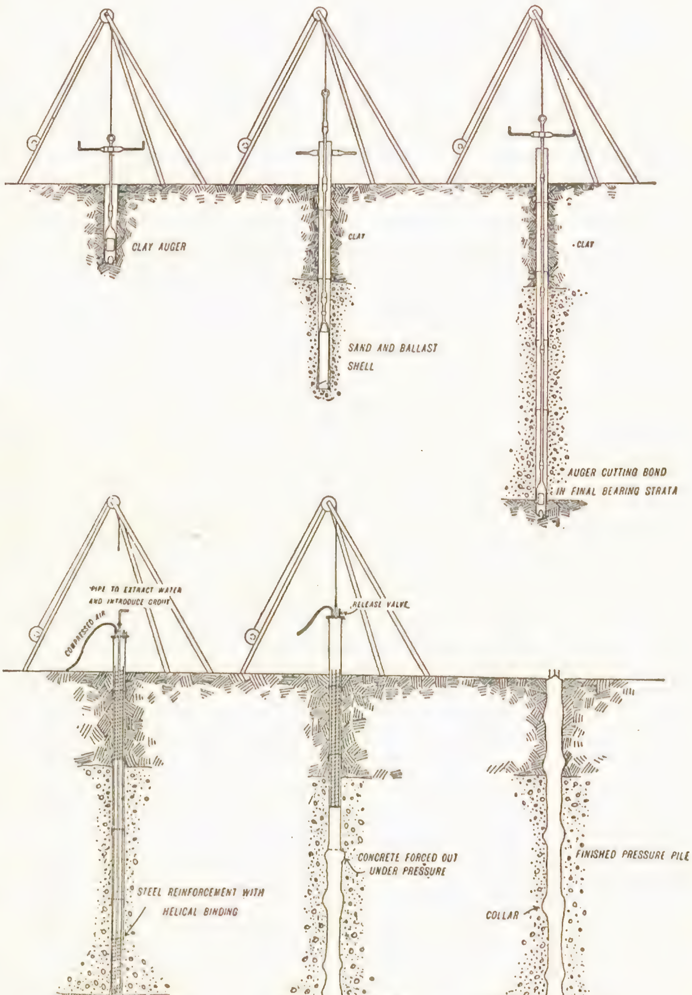


Fig. 114.—Method of sinking pressure piles.

As there is an absence of all vibration in driving, this method enables piles to be driven without any danger to the adjoining buildings. The underlying stratum is thoroughly explored, and the exact length of the pile can be determined. Any desired reinforcement can be used in these piles, and the concrete is subjected to a high pressure, which produces a dense mixture. In this method the concrete is compressed into the subsoil, and collars are formed in the length of the pile, providing high skin friction.

As only a minimum head room of 6 feet is required, and as each pile is compressed *in situ*, the work can be carried out in a very confined area.

Anchors and ties can also be formed by this method, which will resist tension if the piles are properly reinforced. These piles can be driven at any angles that are desired, and a specially good grip on soft soil is provided by a club foot, which is given to the pile at its base by its method of construction.

The method of forming these piles is to sink the heavy boring pipes supplied for the purpose without driving or jarring. This is effected in the manner of boring for wells, and as the ground is excavated through the medium of the pipe, this enables the substrata through which it passes to be thoroughly explored. This last is a very important matter, as it enables the contractor to assure himself that the building is resting on a pile borne by a stratum, the bearing capacity of which may be calculated. On reaching the satisfactory bearing stratum, which may be ballast or firm clay, the boring operations are continued for 2 or 3 feet farther. This enables a thorough exploration of the stratum to be made, and makes provision for the large base or key. The boring tubes are raised up from the bottom of the boring. A steel reinforcement is then lowered and fixed at the correct height for the rods to be properly embedded. A pressure

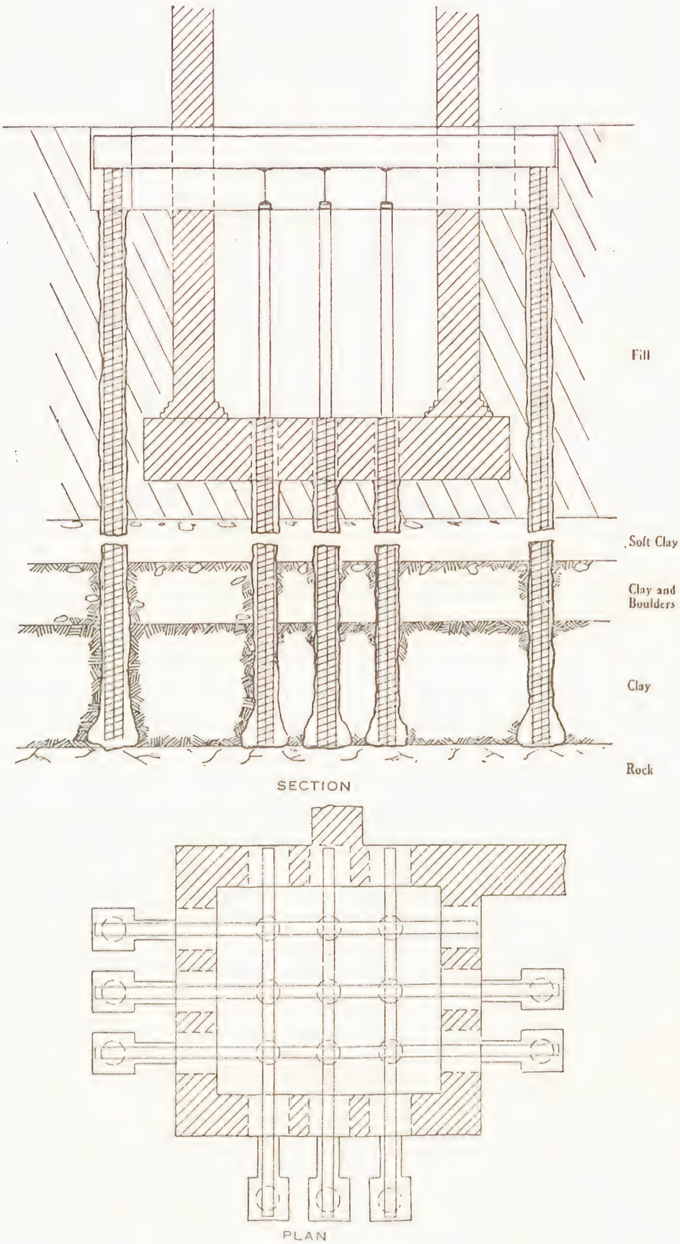


Fig. 115.—Pressure-pile underpinning.

cap is then screwed on, and through the nozzle in this, compressed air is admitted, and all the water within the tube is driven out through a lowered pipe. Cement grout is then introduced under pressure, and air compressed to over 6 tons per square foot is admitted. The grout is squeezed by this means tightly into the cavity, and a club foot is formed at the bottom. The size of this club foot will naturally depend on the strength and compressibility of the bearing stratum.

Concrete is then introduced, and compressed air is also admitted, the air pressure forcing the concrete tightly against the adjoining ground, and squeezes it into all the weak spots in the soil. During this operation the upward pressure of air on the inside of the cap lifts the pipe as the work proceeds. but any possibility of soil or subsoil water getting into the space to be occupied by the concrete is prevented, as the bottom of the pipe is always below the top of the concrete. The process is continued until the pile is completed, when the pipe will lift off of its own accord. If there should be any soft layers of soil in the length of the pile, collars of large diameter may be formed, and the load-bearing capacity of the pile is thereby considerably increased.

As the concrete nears the surface the pressure should be gradually duced, so that the size of the pile at the top may not be unduly enlarged.

It is interesting to note that the diameter of the finished pile, apart from collars formed in weak strata, is generally $1\frac{1}{4}$ times that of the bore of the pipe. The result of this is that the compression on the soil considerably increases the skin friction, and the bearing weight of the pile is thereby also considerably increased.

The suitability of pressure piles for underpinning foundations will be obvious, as often with party walls, for instance, it is impossible to sink piles on both sides of the wall. By this method, however, the piles may be driven in in front of the wall, the reinforcement therein being attached to other reinforcement of a cantilever slab which enters and is pinned in under the wall.

For walls which have a tendency to lean, a combination of buttress and pressure piles sunk at an angle will be found effective, this treatment having been used on church walls that showed signs of failure in this manner.

FRANÇOIS TAPERED STEEL PILE

Another form of pre-cast pile cast *in situ* is that known as the François Tapered Shell Pile, a method designed by the François Cementation Co., Ltd.

Piling as a method of securing safe foundations for both heavy and light buildings has had a rapidly increased popularity in recent years. This is due in part to increased knowledge of the dangers to which even comparatively light structures are exposed in the course of time by such causes as alteration of the water level due to flooding, draining, pumping, and climatic variations, vibrations from the heavy traffic of modern

times, and the effect of adjacent buildings and excavations. To a greater extent, perhaps, it is due to the increasing scarcity and value of good building sites. Building congestion in towns and the value of suitable locations override any question of unsuitability in the ground itself. If safe natural foundations do not exist, they have to be made. There are three ways of doing this: excavation to stable foundation and

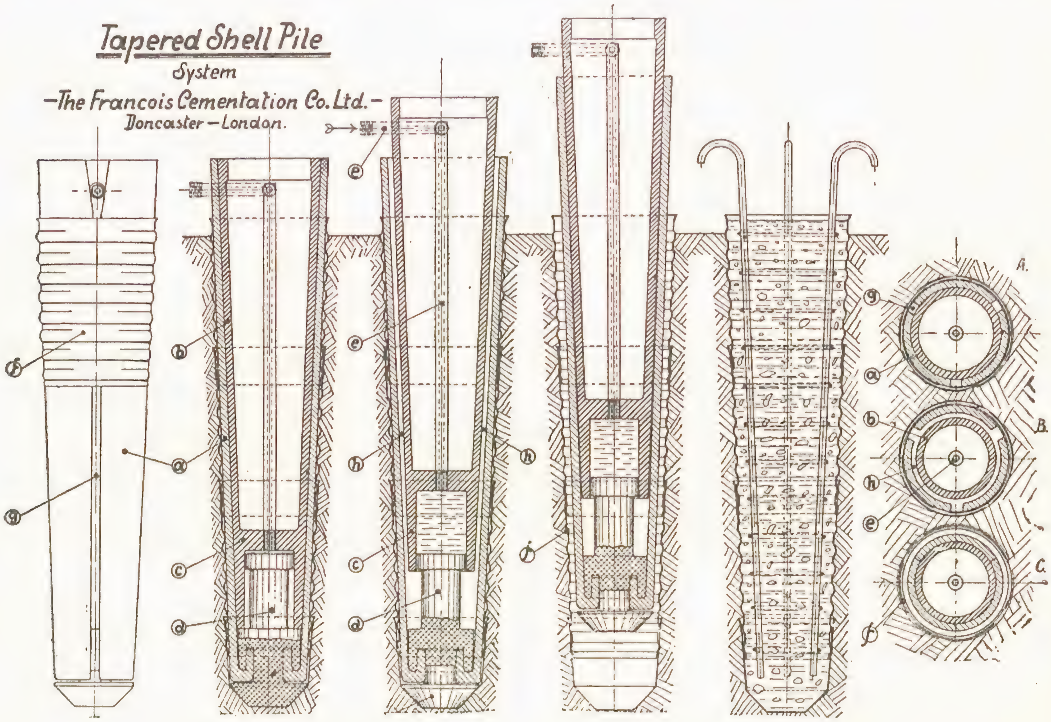


Fig. 116.

a, Collapsible steel ribbons. *b*, Inner core. *c*, "Cylinder" hydraulic jack *d*, Plunger hydraulic jack. *e*, Hydraulic pressure tube. *f*, Corrugated sheet-steel shells. *g*, Gap for collapsible steel ribbons. *h*, Gap in which steel ribbons collapse. *i*, Core point

rebuilding, consolidation of the soil *in situ* by cementation, *i.e.* by the injection of cement grout under pressure, and by piling. The latter two methods can often be advantageously combined.

Since sufficient strength and stability can be obtained by all three methods, choice should depend only on a question of cost or time, or both.

Piling, however, is often unnecessarily ruled out of consideration by questions of expediency; because, for instance, the building site is too congested; it is too difficult of access or lacks sufficient head room, or more seriously, because the dangerous effects of vibration or annoying noise would lead to injunctions and claims for damages. Insuperable as these objections are in the case of piles driven by a pile driver, they can be overcome and other advantages gained by the use of François bored piles.

Methods of Construction.—Two types of bored piles, the use of either depending upon the ground conditions, position of the pile, and the intensity of the load which the pile is required to carry, are constructed.

(1) *The François Bored Concrete Pile.*—The boring is formed and cased by the usual methods to the required depth, a continuous watertight casing being extended through any class of ground until a sufficiently stable stratum is reached. Should it be desired to key the pile into the bearing stratum, even though this is hard rock, it can be done by special boring tools.

When the hole has reached the required depth reinforcement and concrete are inserted, care being taken to ensure watertightness and to prevent an admixture of the soft ground surrounding the pile with the concrete itself. This concrete is consolidated and expanded where necessary by using a light drop hammer, the drop being adjusted according to the ground and site conditions.

Since the concrete is expanded to a greater diameter than that of the boring where passing through weak strata, a pile is obtained with a known minimum diameter at any point along its length ; the strength of the pile from a crushing basis can then be definitely established.

(2) *The François Bored Cementation Pile.*—The boring for this pile is carried out in the same way as for the concrete pile described above.

A specially designed reinforcement cage is inserted, and in addition a central injection tube of mild steel, perforated along its length, is introduced, this tube remaining permanently in position. The boring is then filled with clean screened gravel or ballast, this being introduced in small quantities and lightly tamped, using a drop hammer operating within the reinforcement cage.

This results in a column of compacted gravel left in the ground. Through the injection tube is then forced under pressure a quantity of cement grout, having the effect of thoroughly permeating the ballast and of converting it into a sound shaft of rich concrete, and in addition of tying the pile securely into the surrounding ground, due to the cement penetration. In grounds of a sandy or gravelly nature the whole series of piles can be tied together by this cement permeation, giving a bearing strength which is unobtainable by any other method. This is a direct development of the well-known François Cementation process, and such piles are capable of carrying extremely heavy loads.

Such a pile is, by the nature of its construction, somewhat more expensive than the bored concrete pile, but in the circumstances under which its employment is justified this additional expense is warranted.

Speed of Construction.—Due to the nature of its construction, a bored pile cannot be constructed at the same speed as a driven pile, the speed of construction varying with the nature of the strata in which the pile is formed.

Where the number of piles is few, as is often the case the saving of time by the employment of the François bored pile is considerable, due

in part to the small space occupied by the plant. No time is lost in bringing to the site and erecting heavy pile-driving plant or, as with the pre-cast pile, in awaiting the fabrication and maturing of piles. Moreover, other operations can proceed on the same site at the same time as the bored-pile work, so that the whole work can be better co-ordinated.

Strength of Bored Pile.—The bearing power of a pile depends on the strength of the concrete pile itself against crushing, the ground resistance at the toe, and the supporting power of the strata passed through.

The range of diameters in which the François bored pile can be constructed ensures a pile suited to any requirements within the capacity of the ground on which the work is to be founded.

An example of the load-carrying capacity of the bored pile is given hereunder. This pile was one sunk as underpinning beneath an existing railway bridge, and received no special treatment. It was cast, using ordinary Portland cement, and was tested nine days after construction. The test load was applied through a hydraulic jack, and the first 30 tons applied almost instantaneously. It will be appreciated that such a method of loading subjected the pile to extremely severe treatment, the load being applied almost as an impact.

Load applied (tons).	First reading. Settlement in inches.	Last reading. Settlement in inches.	Remarks.
30	0·033	0·048	Instantaneously applied and three adjustments.
40	0·07	0·09	Three adjustments of jack pressure.
45	0·10	0·112	One adjustment of jack pressure.
50	0·126	0·146	Three adjustments of jack pressure.
Load removed	0·04	0·04	Permanent settlement

Period of test = 4 hours.

Again, the permanent load-carrying capacity of the bored pile is exemplified by the following, where forty-nine François Bored Cementation piles of variable diameter were sunk to carry a chimney the largest of any kind anywhere in the British Isles. The total load upon these piles amounted to 5,250 tons, a working load of 107 tons per pile.

Advantages of the François Bored Pile.—*Working Space.*—Very little head room is required. Where a tall man can stand upright the François bored pile can be sunk.

Accessibility of Site.—No site is really inaccessible. A building site which appears hopeless viewed from a general piling aspect can be quickly and cheaply dealt with by this method. Furthermore, these piles can be sunk through water, *i.e.* in shallow streams, ditches, etc.

Site Congestion and Portability of Plant.—The presence of flying shores and rakers or other timbering is no hindrance.

The plant required for the construction of these piles is of the lightest possible nature. It is reduced to small components, and is in consequence extremely portable.

The very lightness and compactness of the plant opens the way to the piling of a site where access is difficult, and where normal pile-driving gear could not be brought on the site.

Arising further from this, it often happens that only a few piles are required on a site, but to bring to the site and erect a pile-driving outfit becomes prohibitive when the cost is spread over the small footage of piles driven. In such cases the François bored pile scores again—transport and erection charges are comparatively light.

Nature of Strata.—Being sunk by boring, it is possible to sample accurately by obtaining cores of the various strata passed through, and to ensure that the pile footing finishes on or in a stratum of good bearing capacity. Each pile can be sunk to the depth necessary to ensure this, and no apprehension need therefore be entertained as to the stability or strength of the pile so constructed.

Effect on Surroundings.—The sinking of such a pile is free from vibration, noise, or ground displacement. Piles can be sunk hard up against or under footings of existing structures without danger to such.

Flexibility of System.—Piles can be made to any required length and of any required diameter, the former depending on the nature of the strata considered with the safe load of the pile, and the latter depending in turn on these same two factors. The diameter of the pile can be adjusted to meet any particular site conditions. François bored piles are constructed of $8\frac{1}{2}$ inches, $10\frac{1}{2}$ inches, $12\frac{1}{2}$ inches, $14\frac{1}{2}$ inches nominal diameter and upwards if required.

Advantage can be taken along the length of the pile of weak strata passed through by expanding the concrete at such points into collars, these inducing considerably increased bearing value.

Where a resistant stratum is not found within a reasonable depth the pile can be constructed as a *floating pile* by expanding the foot into a bulb, or alternatively, where the question of ground vibration is not paramount, a *composite pile* can be constructed, with the lower portion driven and the upper portion bored.

The pile can, moreover, be protected along its length by a permanent shell, where the ground and other conditions impose the need for such protection.

Verticality.—The pile can be sunk either vertically or at an angle, thus enabling the pile to withstand both direct vertical and inclined compression, and in addition tension.

Reinforcement.—Reinforcement can be inserted in this pile along the whole or part of its length, as required.

Economy.—It will be seen from the foregoing that from a practical and technical viewpoint the François bored pile can be employed advantageously in almost any situation.

On a straightforward site, where conditions are such as to warrant the employment of a large number of driven piles, such piles are, as a rule, cheaper than bored piles. The François bored pile, however, under all other circumstances is economical, and the price per linear foot or per pile will be found to be reasonable.

PILING DATA

Preliminary Estimate.—A preliminary estimate may be made from the following formula of the safe load that a pile will bear when driven if the nature of the ground is known :

$$R = \frac{S_2B}{300} + \frac{LSF}{3}.$$

Where S = width of pile in inches.
L = length of pile driven below ground level in feet.
B = safe bearing pressure at the foot of the pile in pounds.
F = safe frictional resistance of earth on sides of pile in pounds per square foot.

Bearing and Frictional Values on Various Soils

	B.	
Soft river mud	0	0
Soft peat, marsh, bog morass	200	120
Very soft clay	200	150
Ordinary clay	2,500	300
Stiff compact clay	4,500	370
Ordinary sand and gravel	5,500	475

In calculating the set of a pile, no account should be taken of any set less than ½ inch ; the head of the pile should be in good condition, and the pile should have been driven at a uniform rate.

Two forces contribute towards the support afforded by piles : (1) the reaction at the point of the pile ; and (2) the frictional resistance between the surface of the sides of the pile and the soil.

Another formula for the determination of the safe load which may be put on a pile is :

$$W = ra + R.$$

Where W = the safe bearing strength of the pile.
r = the resistance caused by the friction of the soil on the faces of the pile.
a = the area in square feet of the faces of the pile in friction with the earth.
R = the safe resistance to settling determined by the bearing strength of the earth.

The value of r being taken as follows in various earths:

	Pounds per square foot of surface of pile.
Silt or quicksand	No value
Soft clay or silt	150
Hard clay	200–250
Mixed gravel and sand	400–500
Close hard sand or gravel	500–600

Saunders's formula for computing the bearing power of frictional piles is as follows:

$$\text{Safe load in cwts. upon each pile} = \frac{Wh}{8d}.$$

Where W = weight of ram in cwts.
h = height through which ram falls in inches at last blow.
d = distance through which pile is driven at the last blow in inches.

Whilst this formula is satisfactory if the pile is driven an appreciable distance at the last blow of the ram, yet if the penetration is small it gives very high values for the safe resistance in excess of the actual.

This formula may be taken as more satisfactory:

$$\text{Safe load in tons} = \sqrt[3]{\frac{h \times W \times 0{\cdot}23}{d + 1}}$$

where W, h, and d have the same values as in the formula last quoted.

A factor of safety 2 is used when the piles are driven in firm soils, this being increased to 6 for muddy or marshy soils.

The piles are cut off to the level desired when all have been driven, and horizontal sleepers are notched over and spiked to them. Concrete is then fitted in between the framework thus formed. But the principle of having concrete in direct contact with timber is a bad one, especially when the concrete is entirely surrounding the woodwork, as it causes the wood to decay. To prevent this decay, slabs of stone may be superimposed on the heads of the piles, or the cross pieces be of steel joist lengths.

Strength of Struts.—The resistance of the pile having been found, the actual strength of the timber pile to resist crushing may be found from the following formula:

$$R = C\left(1 - \frac{L}{65d}\right).$$

Where R = safe load in pounds per square inch.
L = virtual length in inches.
d = least cross-sectional dimensions in inches.
C = safe compressive stress for short struts.

Values for L in ordinary clay and moist sand = $\frac{7}{8}$ length of pile.
Values for L in stiff compact clay and gravel = $\frac{3}{4}$ length of pile.
Values for C for oak, pine, and teak = 1,600 pounds.
Values for C for red and yellow deals.
Values for C spruce = 1,000 pounds.

CHAPTER 9

DRAINAGE

THE subject of drainage divides itself into three problems: the collection and disposal of surface-water drainage, subsoil drainage, and the removal of human and trade waste from buildings.

DRAINAGE SYSTEMS

When the rainwater from the roofs is collected in a separate drain and led to discharge either into storage tanks or in watercourses, it is known as the *Separate System.* In some districts also there is a separate sewer for the rainwater drainage, though perhaps the most satisfactory arrangement is that in which the water from paved areas and roofs, together with that from the sanitary fittings, is collected in one common drain to discharge into the sewer. A proportion of rainwater provides good flushing to the drains and sewers. In country districts where there is no sewer, and the sewage has to be disposed of by private sewerage installations, the rainwater must be kept separate, as the success of the small sewerage installation depends almost entirely upon the possibility of the filter bed being dried out and aerated at intervals. The rainwater on such a site may either be led into a storage tank, as it is preferable for garden use and washing to company's water, or it may be run in drainpipes away from the building to discharge into a sump or a convenient ditch.

When all of the rainwater is discharged into the foul drain, such drainage is called the *Combined System.*

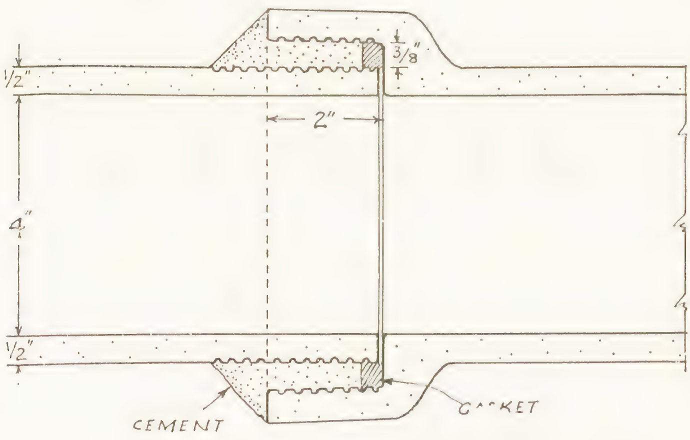


Fig. 117.—Salt-glazed pipe: spigot and socket joint in cement.

DRAINPIPES

For carrying away the waters of drainage, pipes and fittings are used as follows: subsoil water—unglazed earthenware, known as agricultural drainpipes, of from 3 inches to 6 inches, which are supplied in foot lengths and

without collars. These are laid in with the joints butted, some form of covering, such as pieces of bituminous sheeting, being recommended as a covering to the joints to prevent earth from getting in and silting up the pipes. The pipes for rainwater and sewage-water drains are salt-glazed stoneware, or cast iron protected internally and externally against the effects of corrosion. Stoneware pipes are cheaper than cast iron, but cast-iron pipes have certain advantages to be described later.

Glazed Stoneware Pipes.—These are made of a mixture of clay, flint and sand, glazed by using common salt in the kiln burning. The pipes are hard, impervious and durable. They are made to comply with a British Standard Specification in the following sizes :

Internal diameter. Inches.	Internal depth of socket. Inches.	Jointing space, minimum. Inches.	Thickness of pipes and fittings, minimum. Inches.
3	2	$\frac{5}{16}$	$\frac{7}{16}$
4	2	$\frac{3}{8}$	$\frac{1}{2}$
5	$2\frac{1}{4}$	$\frac{7}{16}$	$\frac{9}{16}$
6	$2\frac{1}{4}$	$\frac{7}{16}$	$\frac{5}{8}$
7	$2\frac{1}{4}$	$\frac{7}{16}$	$\frac{11}{16}$
8	$2\frac{1}{2}$	$\frac{1}{2}$	$\frac{11}{16}$
9	$2\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{4}$

Lengths :

Diameter.	Length.
3 inches to 6 inches inclusive . . .	2 feet
7 inches to 10 inches inclusive	2 feet 6 inches
12 inches to 30 inches inclusive . . .	2 feet 6 inches and 3 feet

The provision which has to be made for removing rainfall from roofs equals 0·5 inch in depth per hour ; from flagged areas 0·2 inch in depth per hour ; from gravelled areas 0·05 inch in depth per hour.

Drains and sewers usually provide for removing 5 cubic feet per head in every twenty-four hours, and a house drain requires a velocity of 3 cubic feet per second to keep it clear, whilst 2 cubic feet per second is required for sewers.

Size.—The usual size for ordinary drains is of 4 inches internal diameter, the size of main drains internally varies from 6 inches to 12 inches.

For buildings of moderate size 4 inches is adequate. At this diameter the drain is self-cleansing.

Joints.—Stoneware drains are jointed in the following manner : a 4-inch bore pipe is $\frac{1}{2}$ inch thick, and when jointed in position in the trench each length measures 2 feet. One end of the pipe is widened out into a socket 2 inches deep, and into this socket the other end is fitted. This end is known as the spigot. Both spigot and socket have grooves in them, and their surfaces are left unglazed to give a bite to the jointing material. When one pipe is fitted to another it will be found that there is a space between the spigot and the interior face of the socket. Into this space is inserted tarred yarn or gasket, which serves to tighten the pipes and

keeps them in position whilst the actual jointing with cement is performed. The tarred yarn packing should also be thick enough to prevent any cement from getting inside the pipe. The cement is then pushed in solid all round with the trowel, care being exercised in seeing that the underside is worked in solid as well as the sides and top. A mixture of 1 part Portland cement is less likely to shrink and crack than neat cement. The joint is finished with a smooth chamfered surface at an angle of 45°, and whilst the cement is wet it should be covered with boards or sacking to prevent loose ground or rubbish falling on it. A good-quality Portland cement must be used, but if it is too fresh it will be likely to crack the collar of the pipe owing to undue expansion. Stale cement, however, contracts on setting, with the result that the joint leaks. When cement only is used without tarred yarn, a thin layer of cement is spread round the spigot end of the pipe before it is inserted round the collar of the next pipe.

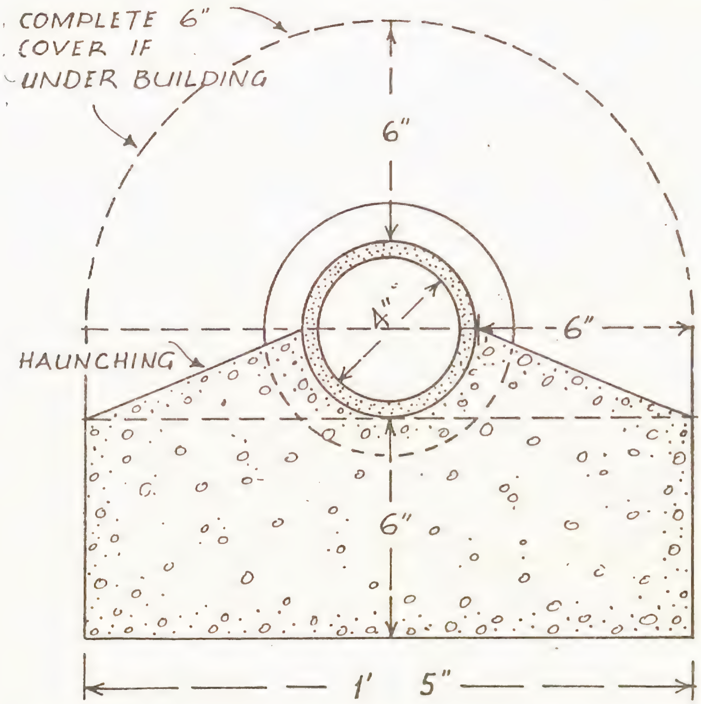


Fig. 118.—Concrete bedding to salt-glazed drain. The curved broken line indicates the complete cover necessary under buildings.

Precaution.—Any solid matter, such as cement setting on the inside of the pipe, will cause obstruction to the flow of the solid matter in the sewage. Consequently, to prevent this, the interior of each section should be cleaned out internally by means of a raker, which consists of two pieces of wood, one a semicircular piece of the internal dimensions of the half-section of the pipe, and the other a straight stick of about 3 feet long attached to the first at right angles, to form a handle.

The following patent joints have been designed for drainpipes:

The Hassall Single-lined Joint.—This is made up of a composition ring forming the end of a collar on the spigot end of the pipe. The socket of the other pipe fits against this ring and has also a composition ring, as in Fig. 119, A.

The Hassall Double-lined Joint is composed of two pairs of rings, of

composition, with a double ring of cement in between. The cement is poured in through a hole in the top, and the splay to the joint is formed by an outer composition ring, as in Fig. 119, B.

The Stanford Joints also have a pair of composition rings. There are deep socket and ordinary socket joints as in Fig. 119, C and D.

Doulton's Invert Shoulder Joint.—In this type the spigot end rests on a shoulder formed at the bottom of the socket, and so that no ridge shall be left internally, it is also provided with a device for keeping the pipes central while the jointing is in operation.

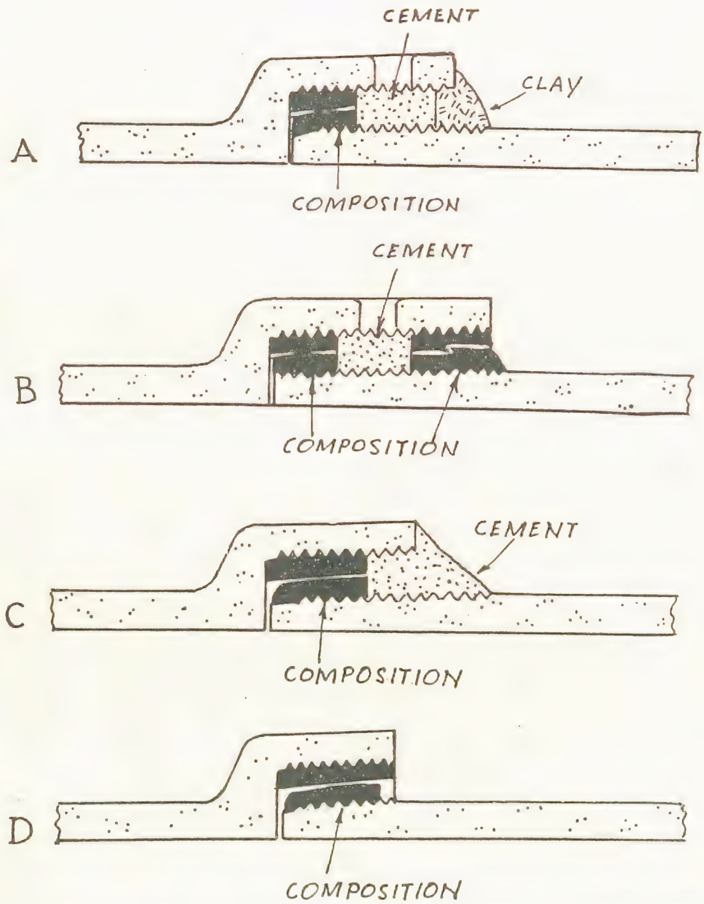


Fig. 119.—Special joints for salt-glazed pipes. A. Hassall single lined. B. Hassall double lined. C. Stanford deep socket. D. Stanford ordinary socket.

Doulton's Grouted Composite Joint combines two distinct joints—an inner seal formed by two bands of composition, one cast on the spigot and the other in the socket, and an outer seal of Portland cement applied in the form of grout. An annular chamber to receive the cement is formed by a band of canvas enclosing a space between the end of the socket of one pipe and a collar on the spigot of the adjoining pipe. One end of the canvas band is attached to the socket, and the other is secured behind the flange on the spigot. The edges of the canvas are secured with binding wires, which are quickly attached. After the joint is completed, the canvas is left in position, and its decay is immaterial. This joint is illustrated in Fig. 120. It is a very convenient and safe joint for salt-glazed sewers. Presence of water in the trench does not impede the operation of grouting. The porous fabric permits the escape of air and superfluous water.

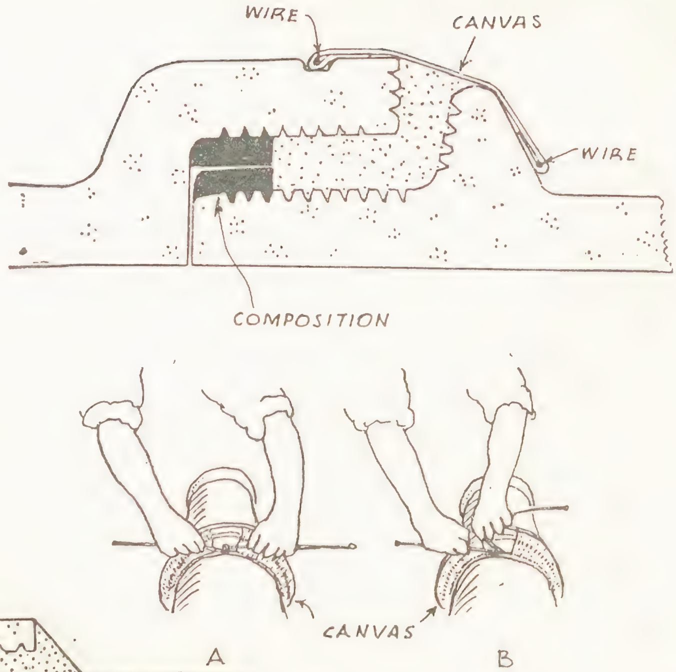


Fig. 120.—Doulton grouted composite joint, used in salt-glazed sewers.

Doulton's Self-centering Joint has the inner end of the socket contracted in diameter, and tapered to correspond with the outer end of the spigot. By the use of plastic cement a preliminary joint is formed, and the joint is completed with Portland cement. With this joint the spigot end cannot drop in the socket of the next pipe. It is specially suitable for pipes up to 12 inches diameter.

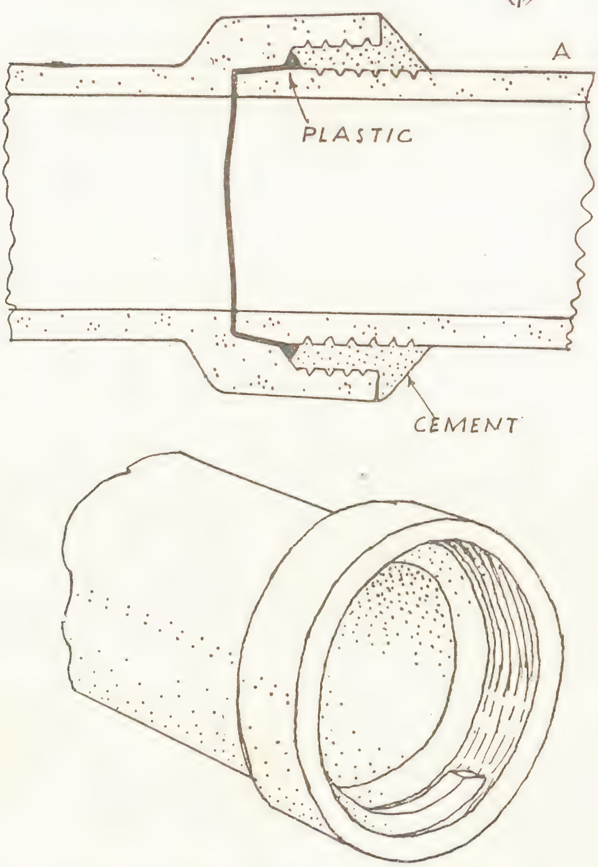


Fig. 121.—(*Top*) Doulton self-centering joint. (*Bottom*) Doulton level invert joint.

IRON DRAINS

Cast-iron Pipes.—These drainpipes are made proof against corrosion inside and out by heating and then immersing in Angus Smith's solution. Though more costly than glazed stoneware pipes, they are made in longer lengths (up to 9 feet), and therefore have fewer joints and the joints are of a more reliable type. They have also greater strength.

Cast-iron drainpipes are strongly recommended where drains must pass under buildings and drives.

They are made to a British Standard Specification in the following sizes :

Internal diameter. Inches.	Internal depth of socket, minimum. Inches.	Caulking space, minimum. Inches.	Thickness of metal for pipes and fittings, minimum. Inches.	Weight per 9-foot length, including socket and beaded spigot or flanges. lb
2	$2\frac{3}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	42 (6-foot length)
3	3	$\frac{5}{16}$	$\frac{5}{16}$	98
4	3	$\frac{5}{16}$	$\frac{3}{8}$	157
5	3	$\frac{3}{8}$	$\frac{3}{8}$	186
6	$3\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{8}$	225
7	4	$\frac{3}{8}$	$\frac{7}{16}$	316
8	4	$\frac{3}{8}$	$\frac{7}{16}$	370
9	4	$\frac{3}{8}$	$\frac{7}{16}$	441

The method of jointing the iron drainpipe consists of a socket and spigot joint. The joint is formed by caulking a tarred gasket. Clay is then placed round the outer edge of the joint to form a gasket, having a funnel or pouring hole at the top. Into this molten lead is poured, and when it is set the clay is removed. As the lead shrinks in cooling it must then be caulked with caulking irons.

This ensures a grip on the metal. "Phil-plug," a cold jointing compound consisting of 90 per cent. asbestos and 10 per cent. cement, is now often used instead of lead. Alternatively, lead wool can be used.

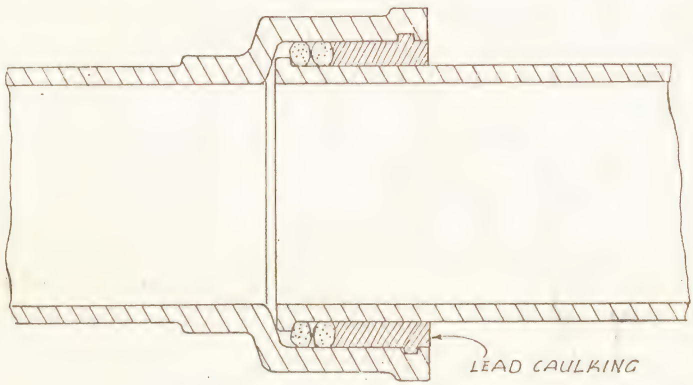


Fig. 122.—Cast-iron drainpipe joint.

The inspection chambers are of cast iron also, and must be provided, in the same way as earthenware drains, with airtight metal covers. These chambers are cast in one piece with all the necessary branch chambers discharging into the main channel, the drainpipes being connected to sockets cast on the chambers by caulking, as already described. To increase the durability of the structure, brickwork or concrete is set around the iron chamber, and an access cover provided at ground level, as in Fig. 125.

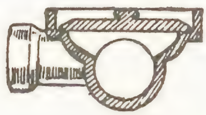
Gulleys and junctions are also to be obtained in cast iron, and the gulleys may be used in conjunction with traps having outlets at the required angles.

Where long runs of iron drains are used for the conduct of water, expansion joints must be provided for.

DETAILS OF DRAINS

In conjunction with the straight runs of drainpipes, there are certain details which must be observed, and for which certain special forms of construction must be used. The principle underlying drainage is that wherever possible the lines of the piping should be quite straight from one end to the other. This is not always possible, as changes in direction will be required, not only to conduct drainage round angles of the building, but also where the inlet to the pipe is at a higher level than the main line of the drain. For this purpose properly constructed *Bends* must be used. For bends round buildings and other sharp bends access covers, or inspection chambers, should be provided.

Section.



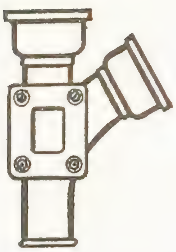


Fig. 123.—(*Top*) Access bend in stoneware. (*Bottom*) Access junction in cast iron.

The curves of all bends should be of as large a radius as possible. Bends of a smaller radius than 6 inches on the inside are termed *Quickbends.*

Junctions. — Closed pipes into which other pipes are run must be provided with a section which is composed of a straight pipe and a curved arm at the side cast in one piece. The curved arm may be of any angle desired and of a diameter to take a smaller pipe. It will be gathered that it is never required or advisable to have a branch pipe of larger diameter entering into a main-line pipe of lesser diameter.

Inspection Chambers.—Where it is required to join two or more pipes together horizontally, the best method to employ is to form a chamber in brickwork, in the bottom of which the junction of the pipes is formed by open half-round channel bends. The actual junctions in the half-round channels consist of purpose-made tapered open channel drains with the requisite number of branches cast thereon in one piece at the necessary angles to receive the branch drains. By this means less obstruction is offered to the solid matter in the sewage, while ready access can be obtained to any stoppage and so removed by lifting off the metal cover with which the manhole must be provided at the top.

The minimum dimension of a manhole should be that into which an ordinary-sized man may gain access: that is, 2 feet 3 inches × 1 foot 10½ inches.

Manhole is the term which applies to any such chamber built round the junctions of drainpipes, and where it is formed as described above, purely for providing access to junctions, it is further described as an *Inspection Chamber*, whereas the last manhole or inspection chamber on the system of drainage within the boundary of the property and before the main

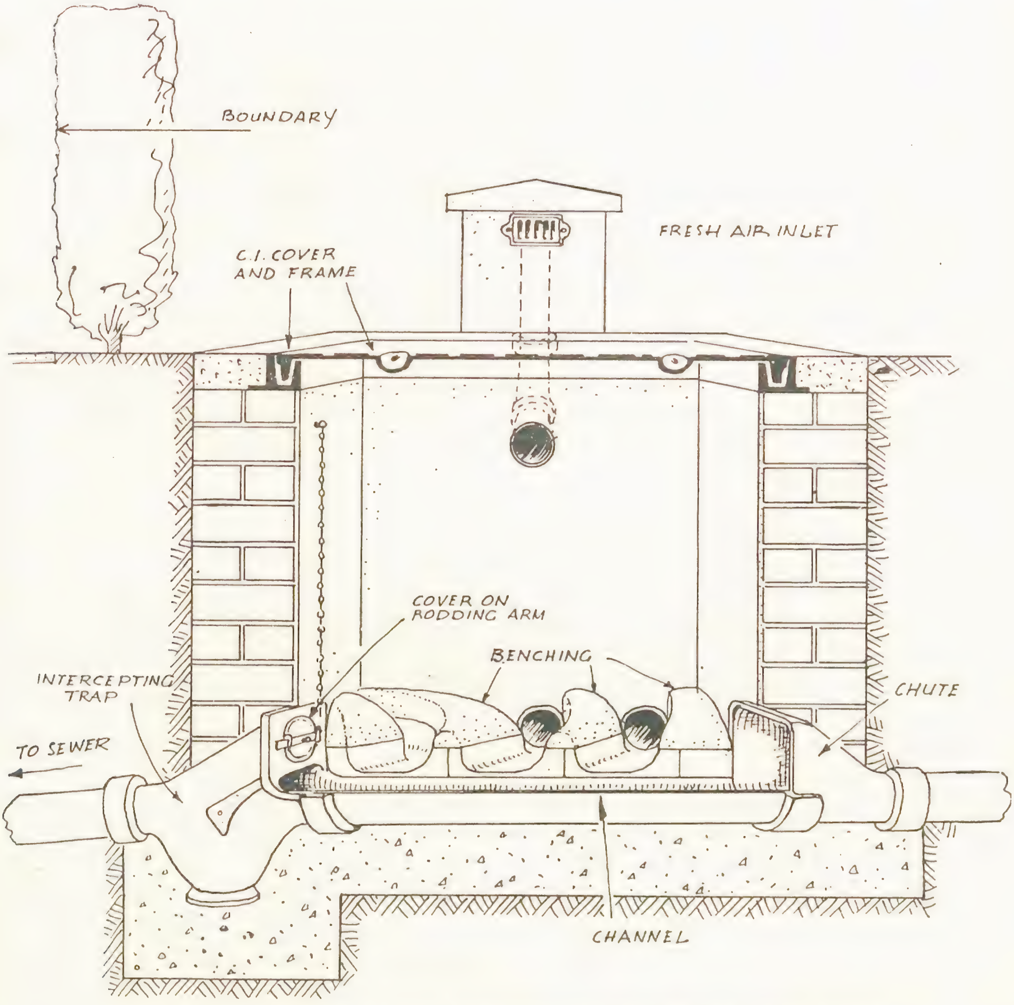


Fig. 124.—Inspection chamber with intercepting trap and fresh-air inlet.

house drain enters the public sewer is termed the *Intercepting or Disconnecting Chamber*.

The manhole is formed of 9-inch brick walls, corbelled inwards at the top, or with a concrete kerb to carry a metal frame into which the metal cover is fitted with a special airtight joint. Impervious bricks may be used, such as dense engineering bricks, blue bricks, or second-quality glazed linings, but the more usual custom is to use ordinary stocks, facing

the interior with $\frac{1}{2}$ inch of cement mortar to form a watertight enclosure. The walls of the chamber rest on a concrete base of at least 6 inches thickness.

The Rodding Eye.—In order to remove any obstruction in the drain-pipe between the manholes, it is necessary to use drain rods which consist of a bundle of rods in 3-foot lengths provided with screwed ends

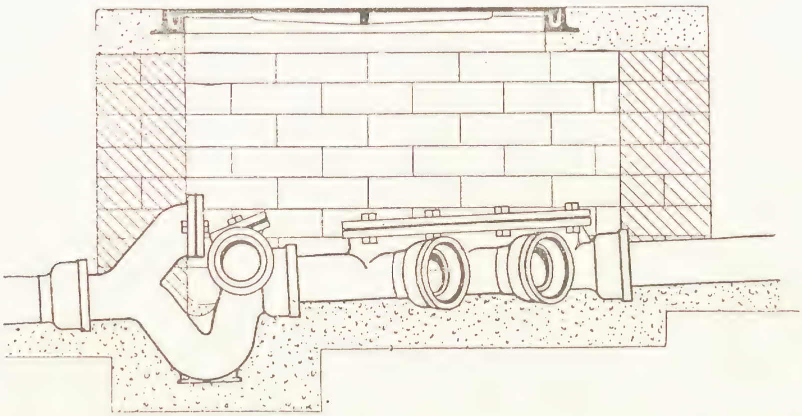


Fig. 125.—Inspection chamber with cast-iron fittings : interceptor and airtight junctions.

to be fitted together to make a continuous run. Though these rods are pliable, it is not always possible to reach the obstruction through the half-open channel band. Consequently in each manhole there should be, wherever possible, a pipe having a specially enlarged end. This is let into the side of the manhole, and the enlargement being caused by the raising of the top side of the end of the eye, it thus renders possible the introduction of the rods at an angle more approaching a straight line than would otherwise be the case.

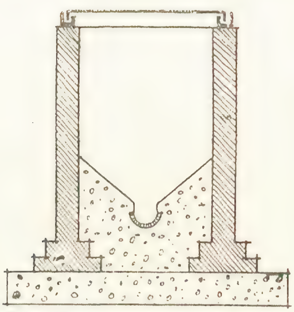


Fig. 126.—Benching.

Where there is a bend in a single line of pipe, a similar line of action for the cleaning rods is provided without the construction of a manhole, and the formation is termed a *Rodding Eye.* This consists of an extension backwards of the drain-pipe in line with the new direction of the pipe, or of a removable cover on the bend or junction.

Drain Chute.—For the purpose of rendering rodding more convenient backwards up the length of the pipe inflowing into the manhole, special pipes are provided known as chutes. These pipes are obtainable with either a spigot or a socket and with a foot for standing on the brickwork or concrete when bedding, and are enlarged at the open end to 10 inches, thus enabling the rods to be introduced at an angle less acute than would be the case if the pipe were terminated in the usual 4-inch opening.

Benching.—To prevent the collection of any solid matter in the angles at the bottom of any form of manhole, these angles should be filled in with solid concrete rounded out and smoothed with cement. This filling is known as benching (see Figs. 124 and 126).

Packing.—The pipes where they enter and leave the manhole in passing though the walls should be surrounded with concrete, which process is known as packing.

DISCONNECTING CHAMBER

This chamber, known as either a disconnecting or intercepting chamber, is situated at the bottom end of the system of drainpipes where the main house drain passes from the boundary of the property to the sewer. It is situated within the boundary and is the property of the building owner. Its main purpose is to disconnect the system from any air contact with the

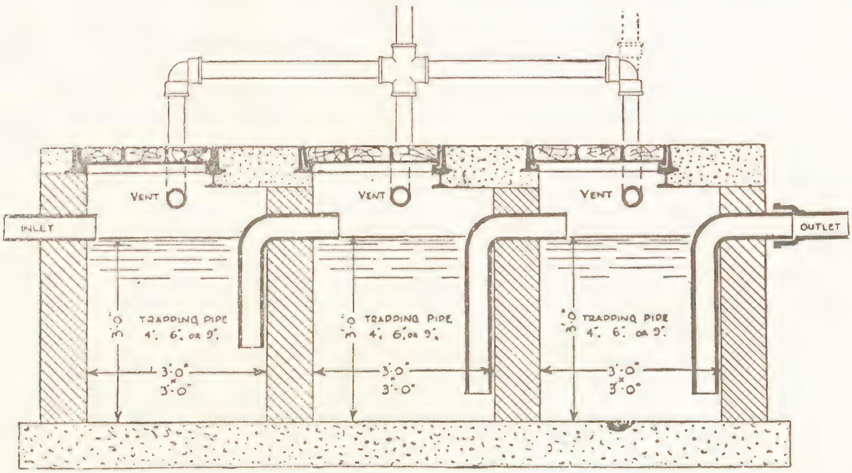


Fig. 127.—L.C.C. petrol trap for drainage in commercial and industrial garages.

public sewer in the road, and for this purpose the exit from the chamber to the sewer is trapped in a manner to be described. Its secondary purpose is to provide an inlet for fresh air to the whole system of drainage within the property.

It is usual to construct a disconnecting chamber, which is deeper than the ordinary manhole, of 9-inch brickwork laid in English Bond bedded and flushed in cement mortar, having the surface rendered with $\frac{1}{2}$ inch of cement mortar, and the whole standing on a concrete foundation at least 6 inches thick, and projecting at least $4\frac{1}{2}$ inches outwards beyond the base of the wall. Owing to the depth which is sometimes required in the construction of these chambers, the interior should be provided with horseshoe steps built into the wall at 1 foot apart to provide a means of descent into the chamber. The minimum internal dimensions of a disconnecting chamber are 3 feet × 2 feet 3 inches. The securing of a perfectly watertight chamber is of the greatest importance, as if the

drains are blocked the sewage will rise in this chamber, when it will exert considerable pressure, unless cast-iron pipes with air and water-tight covers are used.

THE INTERCEPTING TRAP

The outlet to the disconnecting chamber is provided with a trap, the purpose of which is to prevent the passage of any sewer gas from the sewer back upwards into the main house drain, this interception being provided by means of a bend downwards and upwards in the line of the pipe, of such a depth and formation that the bend forms a basin which is always kept full of water. The upper portion of the pipe in its bend projects below the surface of the water in its basin. This formation is known as the *Trap*, and the trap to be most serviceable should hold sufficient water to give what is known as the maximum seal; that is to say, the distance which the upper surface of the bend in the drainpipe projects down below the level of the water in the trap should be the greatest that can be obtained without any interference with the capability of the water in the trap, together with any solid matter that may be brought down, to be completely flushed out each time there is a discharge from the house drain. The line of the new direction of the pipe after it leaves the intercepting chamber is continued backwards and over the trap to form a *Cleaning Arm*. This cleaning arm is fitted with a stopper, properly let into its end. A 4-inch interceptor is ample for the ordinary house-drainage system. It should hold $3\frac{1}{2}$ pints of water, have a 3-inch cascade action and a 2-inch water seal. The amount of $3\frac{1}{2}$ pints of water is arrived at by tests having proved that this amount of water is readily worked by the flow of 2 gallons from the water-waste preventing system of a W.C. If a greater amount of water were to be held in the trap there would be a danger of it becoming stagnant, as it would not be flushed out so completely and solid matter would tend to stay behind. The cascade action, which is the fall down towards the opening of the trap, and should be at least 3 inches, serves the purpose of speeding up the flow as the mouth of the trap is reached. This increases the flushing action.

The stopper end of the interceptor is securely fixed by means of a patent joint of such a nature that if the sewer gas collects in the pipe below the trap in excess the stopper may be blown off, acting in this manner also as a valve. The stopper end is sometimes attached to a chain leading upwards to the manhole cover, so that in the event of it being blown off by the excess of gas, it will not fall into the mouth of the trap. Another form of stopper is made of glass bedded in a thin layer of cement. When it is required to use the cleaning arm the glass has to be broken for this operation, and renewed when complete.

The intercepting trap must be stood on a 6-inch bed of concrete, and should be bedded round with concrete up to the level of a 6-inch bed to the chamber. It will be found to be provided with a flat base. The

bottom of the intercepting chamber is formed by first laying a course of bricks to serve as the base of the walls to the required internal dimensions, and then filling in the space thus formed to the same level with concrete. On this concrete are laid the open-channel pipes with the requisite open-channel branches, and the benching is then formed from the edges of these half-round channel pipes to a height of about 15 inches up the sides of the chamber. The pipes entering a chamber are jointed with the half-round channel bends. The brick walls are then built up to within three courses of the top. These last three courses are corbelled out to reduce the opening to the size required to fit the framework for the manhole cover.

From one of the sides near the top of the disconnecting chamber a 4-inch pipe is led away to a convenient distance, the last joint being formed in a right-angled bend. This is connected to a vertical pipe having its ends fitted with a mica flap fresh-air inlet vent.

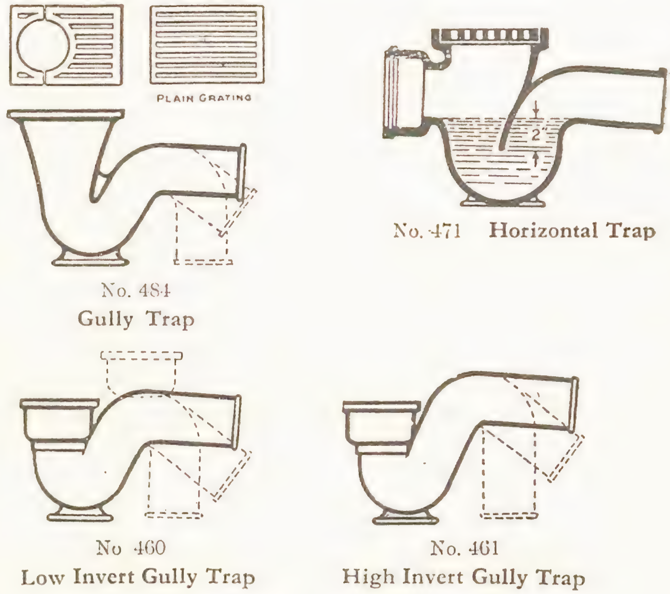


Fig. 128.—Cast-iron traps. (Thames Bank Iron Co. Ltd.)

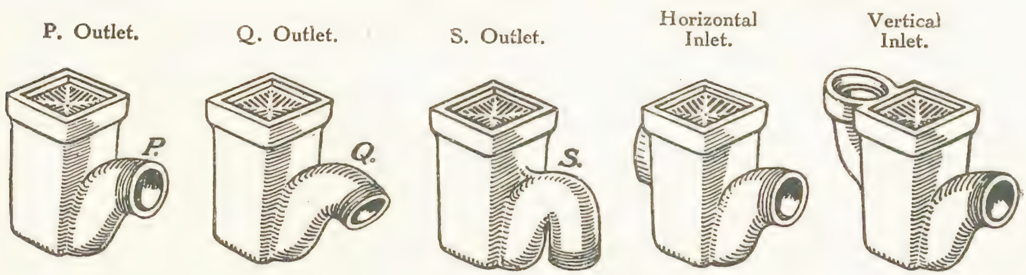


Fig. 129.—Salt-glazed yard gully traps. (Leeds Fireclay Co. Ltd.)

The purpose of this is described later under the heading of Ventilation, though it may be pointed out in passing that the proper ventilation of drainpipes is as important as any other detail of their construction.

GULLY TRAPS

The purpose of traps to drainage systems is to prevent any sewer gas from passing backwards up the system, and so finding its way into the building. In principle a trap is nothing more than a bend in the pipe, which keeps a small pool of water in the basin so formed of not less than 2 inches deep. Every time the pipe is used, and is flushed with water, the water which remains behind in this basin, or trap, is changed, and so is kept fresh. If the depth were to be less than 2 inches, the weight of water when flushed would be so great as to drain the trap completely, with the result that there would be no seal against the gas from the sewer. Where the depth is of 2 inches or more, a certain amount of water is retained, and the seal of the trap is maintained. Traps are fitted, as has been said, at the outlet of the intercepting chamber. There are also traps at the upper ends of the pipes where they enter the ground ; for example, the outlet from the bath and sinks are run into open gullys so that there is no actual pipe connection between the gully and the sanitary fitting. The gully itself is so formed that it is either in itself a trap, or else it is connected to a trap before being connected to the drainpipe.

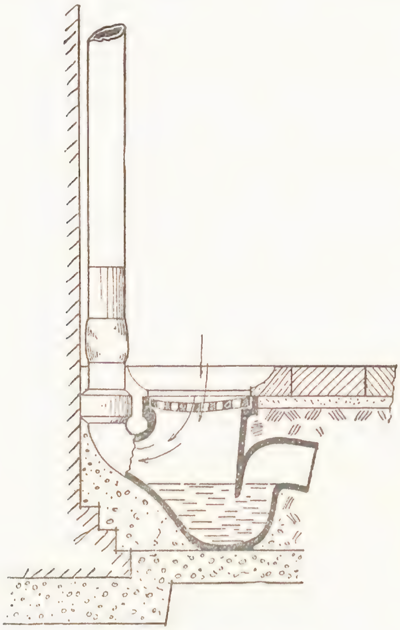


Fig. 130.—Gully trap.

An additional precaution is taken with a bath-waste pipe. This is run through the wall of the house, being trapped at the outlet from the bath, and discharges its waste water into the open air over a hopper or rainwater head fixed at the top end of the bath-waste down-pipe. The lavatory basin waste pipe and the overflow pipes from both these fittings are treated in the same manner. The bottom end of this bath-waste pipe may be fitted direct to the earthenware drainpipe, or it may be fitted with a shoe, bending outwards from the wall, to discharge its water into a grating in an earthenware gully. This gully is a trap.

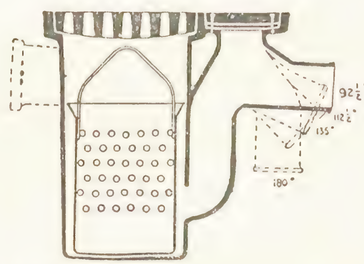
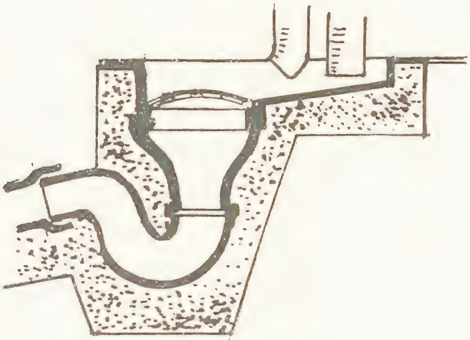


Fig. 131.—Small silt trap. (Burn Bros. Ltd.)

The pan of the W.C. fitting is itself a trap. This passes through the wall of the building and is connected to either a lead or cast-iron pipe, which is in its turn connected to the main drainpipe. This lead-down

pipe is carried up to a height above all other connections, and to a distance of at least 10 feet from the nearest window opening, to form



'Fig. 132.—Channel and gully.

Anti-Flooding Ball-Valve
Int 'rceptor

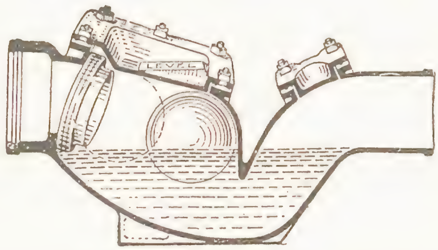


Fig. 133.—Prevents back flooding by forcing the copper ball against the seating.

an outlet ventilator. At the extremity of this should be fixed a wire case to prevent birds finding entrance.

VENTILATION

It will be seen that a provision has been made to admit fresh air into the system of drainage at its bottom end and an exit has been provided for any foul air at its top end. The inlet, as was pointed out, is placed near the top of the disconnecting chamber, and the outlet is at the head of the untrapped soil pipe.

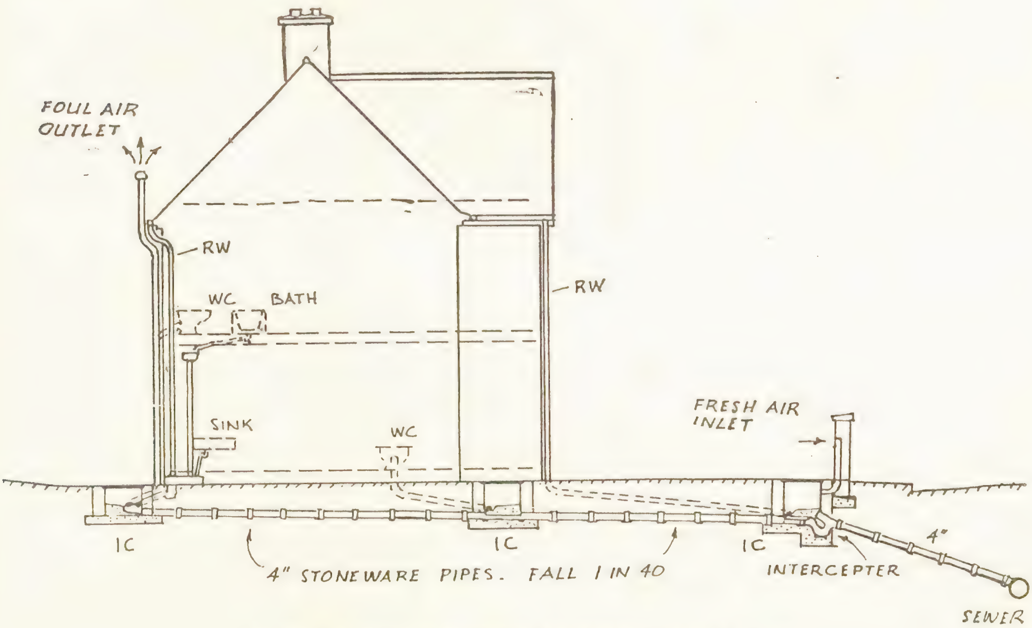


Fig. 134.—Section illustrating the drainage of a house.

It might be thought that the proper place for the outlet of foul air would be at the bottom of the system, as every time the system is flushed the direction of the air from the inlet upwards to the outlet is reversed. But the after-effect of this is that the flow of water having carried with it a certain amount of the air in the pipes, when this flow has passed the trap in the intercepting chamber, a partial vacuum has thereby been created; new air must be sucked in to take its place, and it is natural that the most serviceable point at which this fresh air may be introduced is a point as near as possible to the lowest point of the drainage system at which the air was sucked out. The result of this is that air being sucked in, it will take the place of that sucked out; passes up the system, and a circuit of ventilation is established from the inlet at the disconnecting chamber to the outlet on or above the roof.

JUNCTION OF LEAD, IRON, AND EARTHENWARE PIPES

Lead to Earthenware.—As was said above, the outlet from the W.C. is a lead pipe which is joined either to an iron or to an earthenware pipe. Where the lead is joined to earthenware a socketed brass thimble is fitted on the lead pipe to give the joint stiffness, and the thimble passes within the lead to avoid any obstruction within the pipe. The junction is then wiped in the usual manner.

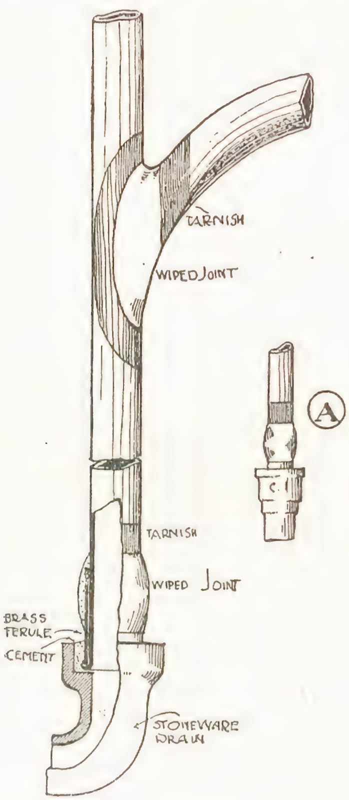


Fig. 135.—Joints used between lead and stoneware pipes.

Iron to Earthenware.—For joining an iron pipe to an earthenware pipe, the end of the earthenware pipe is formed into a socket of the required dimension to take the end of the iron pipe and to leave an annular space which is packed with yarn gasket and filled in with neat Portland cement.

Joints Generally.—Care should be taken to make airtight and durable joints. As these joints are usually in positions in which the points farthest from the workman are difficult of access, being either on the ground or against a wall, work in such a position being difficult it is often scamped, but at the first test such neglect will be obvious, and the cost and trouble of repairing the neglect will be considerably more than any saving that might have been thought to have been made.

SIZES AND GRADIENTS OF PIPES

The fall which is given to a drainpipe is important. Whereas it might be thought

that the steeper the inclination the better, this has been found not to be so, for the result of a gradient that is too steep is that the liquid runs away before the solids, whereas what is required is a gradient which gives a steady flow of all the matter in the pipes together. The normal velocity of flow required is about 2·5 feet per second, and this is to be obtained in 4-inch drainpipes of smooth interior surface by a fall of 1 in 40.

This gradient, however, naturally depends on the internal dimensions of the pipe. Consequently, the following table gives the gradient for pipes of different internal diameter:

3-inch drains	1 in 30.
4-inch drains	1 in 40.
5-inch drains	1 in 50.
6-inch drains	1 in 60.
9-inch drains	1 in 90.

The amount of the fall available will depend upon (*a*) the depth to the sewer or other point of outfall; (*b*) the total longitudinal distance the drain has to run; and (*c*) the depth at which the drain commences. If sufficient fall cannot be obtained, an automatic flushing tank must be fixed at the head of the drain to discharge periodically. It is now thought preferable that drains should be, as a general rule, smaller than might be thought to be required. For example, the discharging powers of 4-inch and 6-inch drains can be realised by a comparison of their cross-sectional areas.

Cross-sectional areas: 4-inch pipe = 12·566 square inches,
6-inch pipe = 28·274 square inches,

the latter giving more than twice the cross-sectional area of the former.

The diameter of the drains should be in proportion to the work they have to perform, but for houses and other small buildings 4 inches diameter is adequate. Even in much larger buildings most of the drains should not be more than 4 inches.

Size.—The size of the main drain, though now generally accepted as being established by experience, may be worked out from the following formula:

$$D = \sqrt[5]{(\sqrt{(d)^5} \times N)^2}$$

where D = diameter of main drain;
d = diameter of branch drains;
N = number of branches.

Gradients.—A simple rule of thumb to determine the gradients of drains to provide a satisfactory velocity is the following:

Multiply the diameter of the pipe by 10, and the result gives the gradient for the drain.

Thus, a drain of 4 inches diameter, multiplied by 10, gives a gradient of 1 in 40, and for a 6-inch drain 1 in 60.

LAYING THE DRAINS

The first step necessary is to peg out the lines of the drains from the drainage plan.

The disconnecting chamber and manholes must also be pegged out, and excavated to the required depth. This depth may be ascertained by considering the gradient of the drain and levels of the site, and the trenches should then be dug to the proper falls.

The next step is to cover the manhole bottoms with 6 inches of concrete, and the drain trenches with 3 inches of concrete.

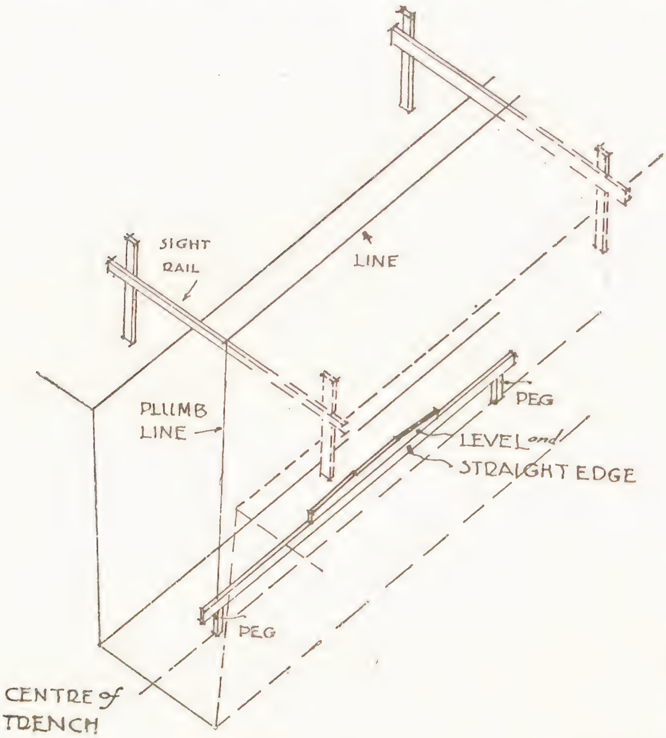


Fig. 136.—Laying drains.

In most specifications a clause will be found that all the drains are to be left open for inspection by the architect until they have been properly tested and finally approved. Should there be any existing drains these will require to be taken up where directed, or broken into and properly connected to the existing drains. The connection to the sewer must be performed as required by the Local Sanitary Authority, and is generally carried out by them. The contractor, however, has to pay all fees and other expenses in connection with this work.

Stoneware drainpipes should be laid on a 6 inches thick bed of concrete unless the subsoil is very firm. The sides should be haunched with concrete halfway up. If pipes pass under buildings they must be completely surrounded with 6 inches concrete.

It should be noted that the laying of the drains is commenced at the lowest point, *i.e.* from the disconnecting chamber, and all the necessary branches must be inserted as the work proceeds. The lines of branch drains are then started at the point of junction with the main drains.

In order to attain the required level after the trench has been dug, pegs are driven into the ground at the bottom of the trench at certain measured distances apart. On top of these pegs the level is placed, and

the required fall measured in inches down the pegs from the level. For example, if a fall of 1 in 40 is required, and the length of the straight run of the trench is 20 feet, then the pegs are driven in one at the beginning of the straight run, the next at 10 feet, and the other at 20 feet from the first. The level and straightedge are then placed on the top of the first two pegs, the pegs being driven in to give a true reading. When the

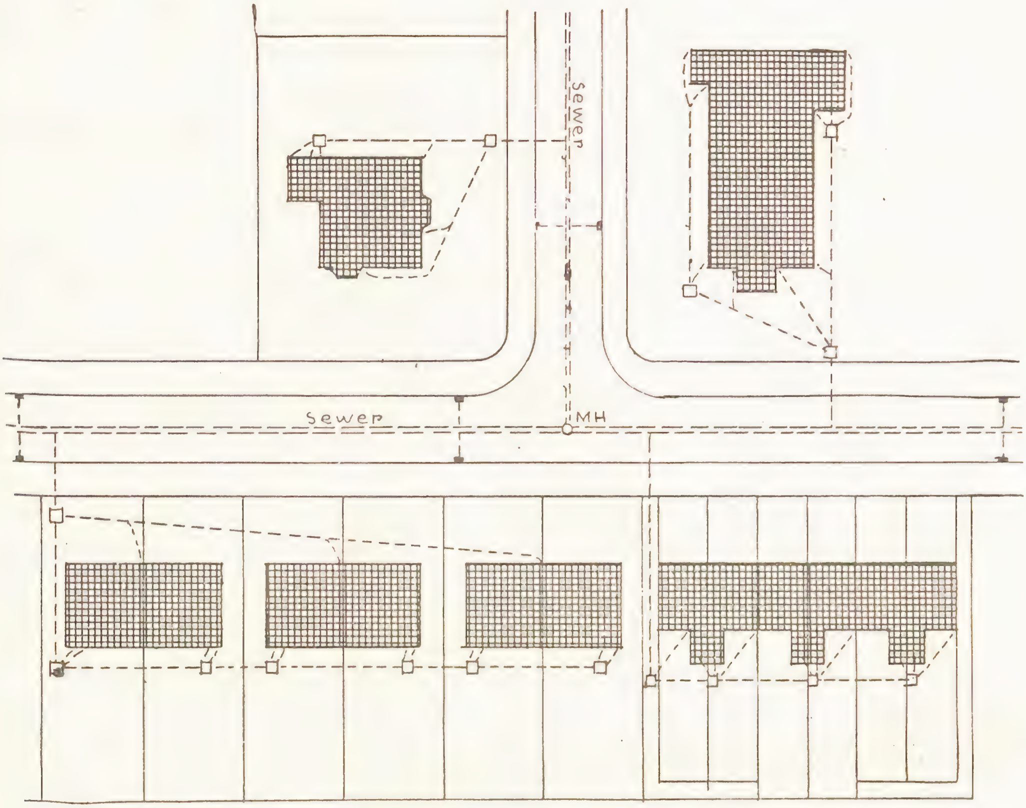


Fig. 137.—Part of town drainage plan, showing sewers and connections from private drains.

third peg has been treated in the same manner, a line passing over the top of the pegs will be level for a distance of 20 feet. As the required fall is 1 in 40, this equals a half in 20, and a quarter in 10. A quarter of a foot in 10 feet equals a 3-inch fall. A distance of 3 inches therefore is marked down from the top of the second peg, and a distance of 6 inches from the top of the third peg.

In order to facilitate the laying in of the concrete the pegs may be driven a distance marked on each of them into the ground, and the concrete then levelled up to the top of the pegs. Where the trenches are in long lengths of straight lines their levels should be tested by means of boning rods. The sight rails are fixed at each end of the straight trench at right angles to the line of the drain, each at a known height

above the invert, thus providing a line joining the two rails at the same constant height above the invert in any part of its length. A bricklayer's line may be stretched from the centre of one sight rail to the centre of the next sight rail.

In order to obtain correct fall to the bottom of the trench a boning rod of the required length equal to the distance between the bottom of the trench and the top of the sight rail will give the correct depth of the trench at any point in that line within the two sight rails. This will afford the required fall.

In order to obtain the correct fall in the drainpipes, the boning rod must be fitted with a special foot attachment at right angles, so that it may enter within and lie upon the invert of the socket.

Levels are to be obtained with adjustments at each end which may be set to the required angle which the fall of the drain makes with the level line. Such an instrument when showing that its top line is level will give at its bottom line the fall or gradient at the bottom of the trench or the invert of the pipes, each of which may be measured down to by means of the boning rod last referred to, or by an ordinary measuring rod.

A Gradiograph is an instrument constructed on the principle of a straightedge and spirit level as described above, and is placed inside the pipe to ensure that the two ends of the invert of the pipe are in the correct line of gradient. Its edges may be adjusted out of parallel to the extent of the inclination of the drain.

THE DRAINAGE OF SMALL BUILDINGS

The drainage of houses and other small buildings is usually carried out in salt-glazed stoneware pipes of 4-inch internal diameter, with socket and spigot joints jointed with a gasket and a Portland cement and sand mix. In all but very firm subsoils the drains are laid on 6 inches concrete.

The drains should have a minimum fall of 1 in 40 towards the sewer or other connection.

An intercepting trap and chamber is placed near the boundary between the drain and sewer connection as shown in Figs. 134 and 138. A fresh-air inlet connects with this chamber. A foul-air outlet is placed as near as possible at the head of the drain. This is usually in the form of a combined soil and vent pipe, the vent portion being a continuation of the soil pipe to the upstairs W.C.

The bath, lavatory basin, and sink wastes are connected to the foul drain. The sink waste discharges into an open channel or dished way, at the lower end of which is a gulley trap with iron grid. It is advisable to use a small grease trap at this point. The bath and lavatory basin waste is discharged into a waste head with cast-iron down-pipe (if upstairs). This may discharge into an open dished way leading to a gully grid, or be connected to a gully trap with side connection.

Rainwater down-pipes when discharged into the foul drain have a

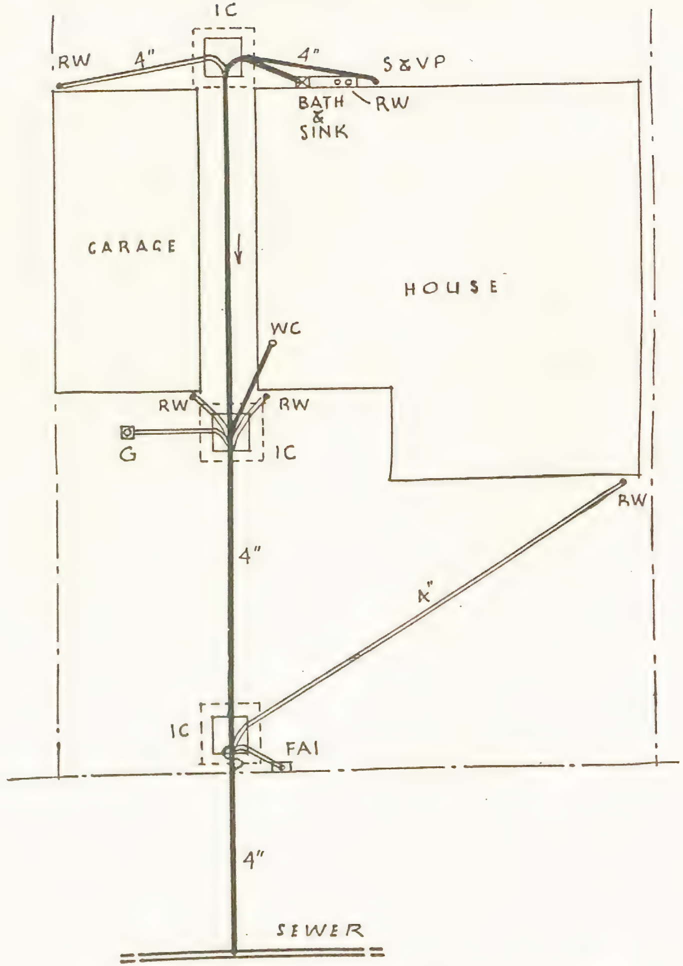


Fig. 138.—Plan of house drains: foul and surface water combined.

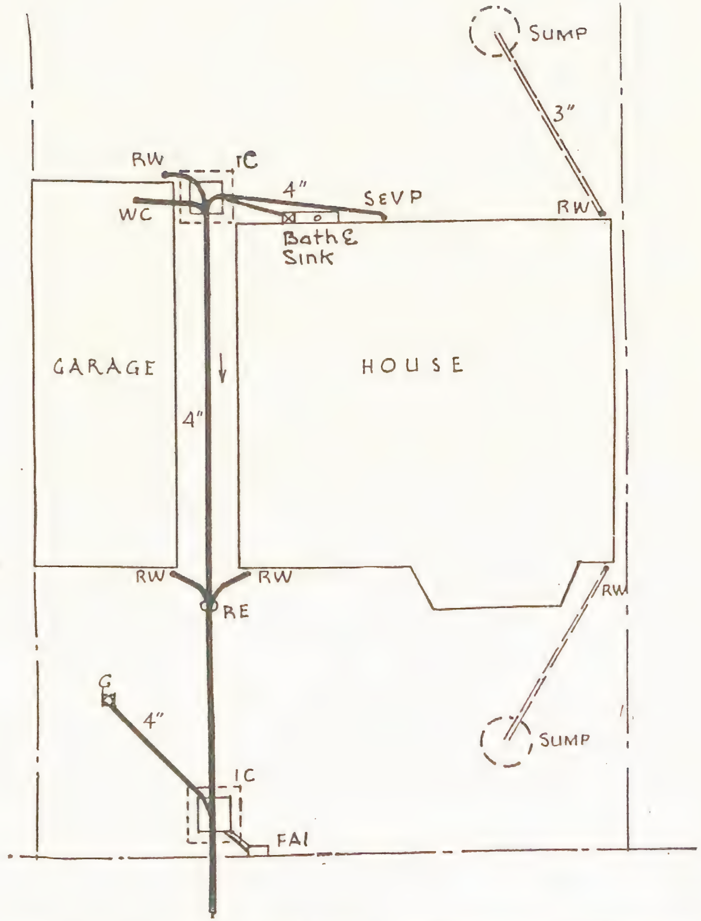


Fig. 139.—House drainage pian: foul-water drain connected to sewer, surface water to sumps.

projection fixed at the bottom of the down-pipe giving an open discharge over a gully fitted with grid and kerb. Alternatively, the down-pipe may be connected to an untrapped rain-water shoe, provided a trap is placed between the rainwater drain and its junction with the foul drain.

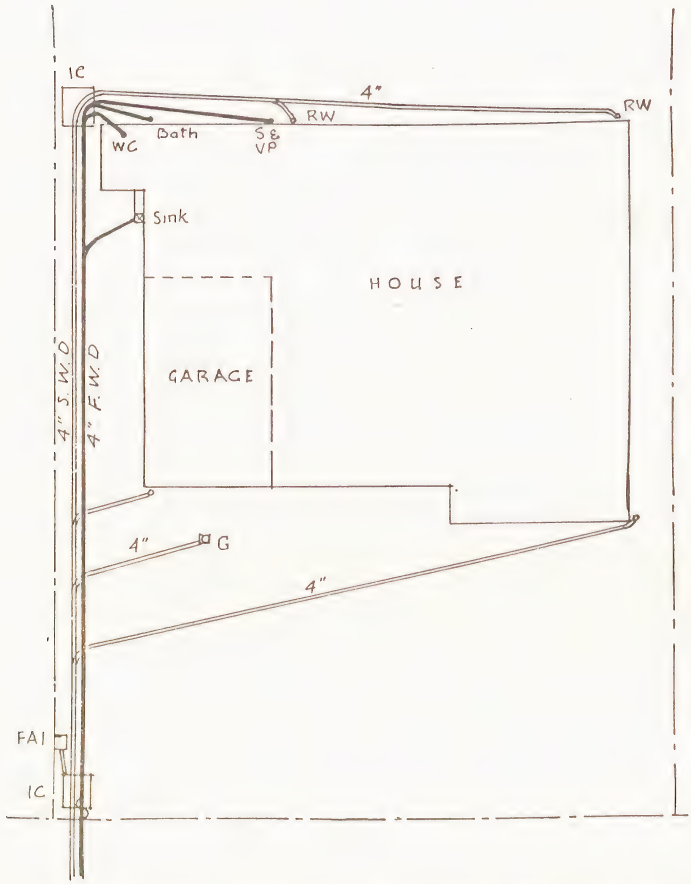


Fig. 140.—House drainage plan : separate foul and surface water.

In case of drain stoppage it is a convenience to have inspection chambers at all sharp bends and junctions. But not all authorities recommend this practice. Where connections and junctions can be made without sharp angles one inspection chamber at the front boundary is sometimes considered sufficient.

Private Drainage Systems.—Where drainage is to a cesspool or septic tank, it is necessary to separate the rainwater and drain it into ditches, streams, or a soak-away in absorbent ground. The foul drain should be fitted with a disconnecting trap and inspection chamber close to the cesspool or septic tank. It should be ventilated and all connections trapped, as with drains connected to a public sewer.

A variety of traps and fittings are made which have special advantages. Public garages and washing-down yards should have petrol traps, as in Fig. 127. Where much grit or mud may be washed into a gully it

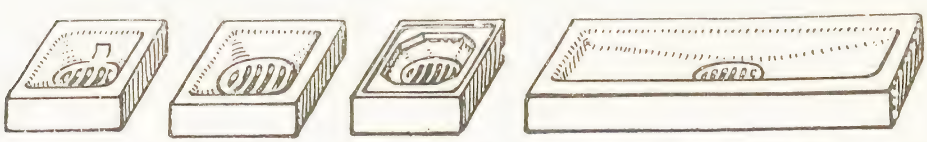


Fig. 141.—Glazed dish bricks and channel dish. These are fitted on traps or shoes for open discharge of R.W. and waste pipes. (Leeds Fireclay Co. Ltd.)

should have a deep grit bucket, as in Fig. 131, which should be periodically removed and emptied.

THE DRAINAGE OF LARGE BUILDINGS

Special problems arise in the drainage of many large buildings. Buildings covering a large ground area have long lines of drains with a considerable overall fall. If the sewer is only a few feet below the road and the site has a backfall it may be necessary to have more than one sewer connection.

Sewage Pumps.—With such buildings, and also where sanitary fittings have to be fixed in basements below the sewer level, pumping plant is often the only way out of the difficulty. A duplicate installation is necessary in case one set breaks down or requires overhaul. The second set should be arranged to come into action automatically on the breakdown of the first.

In large city buildings where there are only a few small open areas some of the drainage must be laid inside the building. Cast-iron or lead soil and waste pipes are suspended from ceilings or laid in special ducts. Deep beams often complicate matters, so that it is advisable to plan the sanitary arrangements at an early stage and enlist the sympathetic co-operation of the structural engineer. For the more awkward runs lead is more adaptable than cast iron.

Inspection covers bolted down should be used at sharp bends. The

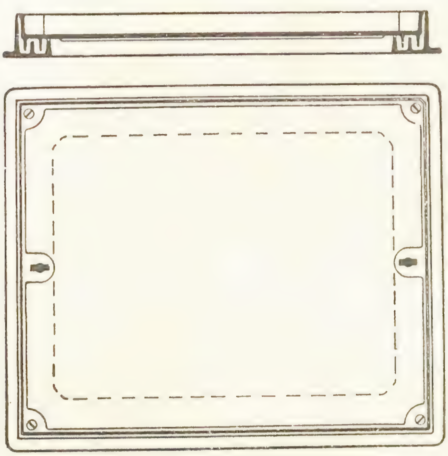


Fig. 142.—Inspection cover for filling with concrete.

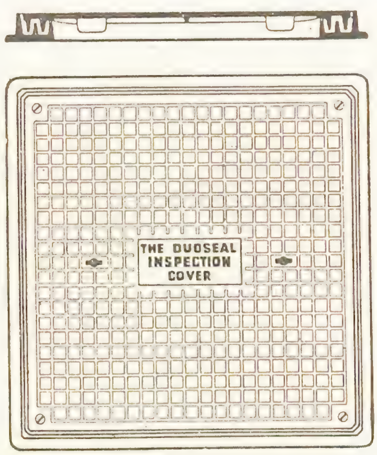


Fig. 143.—Inspection cover with non-slip iron surface.

interceptor and inspection chamber is usually arranged in an area or forecourt.

The One-pipe System.—The drainage of tall city buildings is greatly simplified by using the one-pipe system, in which the lavatory and sink wastes are connected to the vertical soil pipes. This saves all the vertical

piping of a separate waste system, and also greatly simplifies the gully and drain connections. The one-pipe system is described and illustrated in Vol. IV, Chapter 2.

The drainage and sanitary system of large buildings is usually designed by a consulting sanitary engineer.

CONCRETE DRAINPIPES

Drains are made of concrete of 6 inches in diameter and upwards, but pipes of the larger dimensions should be reinforced with rods or expanded metal. The concrete must be rendered non-porous, and the joints are formed of an ogee section. These pipes are cast in 2 to 3-foot lengths and $1\frac{1}{2}$ to 3 inches in thickness.

TESTING DRAINS

In all specifications there will be found a clause that the drains must not be covered up until they have been tested in the presence of the Architect, and also the District Surveyor. There are four methods of testing drains.

The Water Test.—This is sometimes called the hydraulic or hydrostatic test, and provides the best test for drains. The first necessity in order to make this test is that the system in its lowest point should be plugged. This is effected by a plug and bag or a special screw stopper designed for the purpose. The whole system, including the manholes, is filled with water and allowed to remain so filled for some hours. If there is any leakage it will be seen in the lowering of the water in the manhole, and if this is not occurring past the drain stopper, the water must be finding its way through leakages in the manholes or in the joints of the drainpipes. At the same time it should be recollected that in new drains there will be a certain amount of water absorbed at first by the new materials. Consequently, the customary half-hour recommended for the water to stand before the test is made is not sufficient to give a satisfactory test. It is preferable that the drains should be filled up overnight and again filled up next day when they are to be tested. It is also important to make certain that there is no air lock anywhere in the length of the drainpipe, or the air escaping later from this will cause a considerable lowering of the water. In order to overcome this, a piece of rubber hosepipe pushed through any traps will be found effective. Another method for removing any possibility of air locks is to bale out the water from all the traps before filling.

When the inspection chambers are filled as well as the drain, it is necessary to mark the water level on the chamber wall. An alternative and better method is to use a 2-gallon measure connected to the lower drain stopper. By this means the length of drain only is filled with water, and there is no absorption into the inspection-chamber walls and floor.

Locating the Leak.—Where it is obvious that there must be a leak, the next point is to locate it. And in new work it is often difficult to find a small leak by the water test, where most of the ground and materials are to an extent damp.

The Smoke Test.—This test is mainly useful for drains having steep gradients and for pipes in vertical positions, but it is not so effective as the water test.

In this test also there must be pressure, and this is supplied by a machine consisting of a tank and smoke box to which a bellows is attached. In the tank oily cotton waste is burnt, which gives off a combination of thick smoke and a pungent smell. The wind pressure is supplied by the bellows, and if the pressure is sufficient, the smoke will find its way out of any leaky joint that there may be. It is somewhat doubtful, however, if the covers to the manholes would prove sufficiently airtight for this test without having the joints sealed with putty or cement, and it is

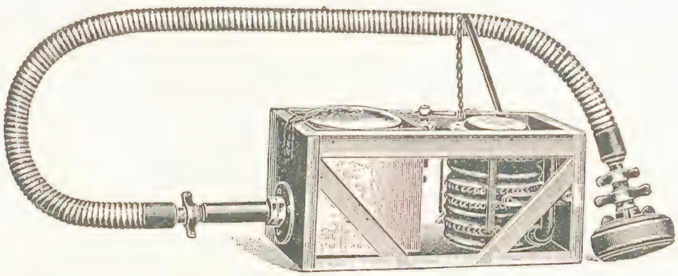


Fig. 144.—Drain-testing machine for smoke test. (Burn Bros., London, Ltd.)

desirable that only a section at a time should be tested by this means, and the upper end of the section of drain under test will require to be stopped. However, tests of a whole system are sometimes carried out with smoke, in which the smoke is forced in through the vent pipe to the intercepting chamber, the gullys having first been dried out and all the openings stopped. Care must be taken not to unseal the traps by exerting too much air pressure. The dome of the smoke box should retain its elevation. A fall indicates leakage.

The Pungent-smelling Test.—This test is particularly suited to old drains where a leak is feared, as if a sufficiently pungent chemical be used, and a sufficient time be allowed, the odour of the chemical will percolate upwards through shallow ground, provided it is not clay. This will save considerable time in excavating. Probing the ground will help leaking odours to escape.

The test consists of introducing a strong-smelling chemical into the pipes. The same remarks as to stopping apply in this as to the smoke test. The cardboard cylinder in which the chemical is contained, known as the Rocket, has a small spring in compression inside it, and when

the cardboard is wet through, the spring is sufficiently strong to burst it open and allow the chemical to escape. Oil of peppermint can be used instead.

The Air Test is suitable for soil and waste pipes only, and is performed by stopping all openings as before, and forcing air into the system by means of a pneumatic pump fitted with a pressure gauge. When this is allowed to stand, a falling in the reading of the pressure gauge will denote a leakage, though it will not disclose the actual point at which the leakage is taking place. For this, a combination of the air test and either the smoke test or the pungent-smelling test will be helpful, and for this the machine already referred to will be required.

Where the leak is only a small one, it is sometimes possible to trace it by the sense of smell alone, and to make sure that any test is satisfactory, it is really necessary that each section should be tested separately.

Where a test is being made of the whole system at once, and it is impossible to discover in which section the leak is, this may be traced eventually by emptying the system, section by section, though this really comes to the same thing as testing each section separately, only that it causes more trouble in the long run.

REPAIRING THE LEAK

When the leak is caused by an improperly made joint there is no great difficulty in its repair, but where it is due to a cracked collar, or to a cracked drainpipe, the removal of a single drainpipe without cracking the adjoining one or the joints is a more serious matter.

In order to remove a drainpipe which is cracked, the upper half of the collar of the pipe below the cracked pipe must be cut away, and the underneath half of the cracked pipe collar must also be cut away. A new pipe is then inserted, having the underneath half of the collar only. After the new pipe has thus been fitted into position, the removed halves of the collars to both pipes are made good in cement.

Renewing Half-round Channels.—Where half-round channels in manholes are cracked, any attempt to repair these cracks is at the best an unsatisfactory operation, and only of a temporary nature. The whole section of cracked channel must be cut out and replaced.

In resetting the new channel the cement must be very carefully smoothed into the joint, as any projection in this will cause obstruction to the solid matter, and in the long run will be the cause of another leak in that it will be broken away by this constant friction.

Making New Connections.—Where new connections are required owing to an increase in the number of branch drains, the shortest plan is to remove the existing channel entirely and to substitute one having the requisite number of junctions.

Leaking Manholes.—Leaks in manholes are generally caused by the wrong proportioning of the cement rendering, and the leak will generally

be found in the corners. Any such defect in rendering should be re-rendered with cement 1 part to 2 of washed sand with an admixture of waterproofer. Extra thicknesses should be run in the corners, and if any cracks appear at the junctions of the benchings and the open channels, these should be wedged up in neat cement.

In inspecting and testing existing systems of drains, it is wise to take particular note of benchings, and if there are found to be any level surfaces in these, they should be made sloping by the addition of cement rendering.

It will be found impossible to repair the rendering to a manhole which has been in use for some time without thoroughly hacking the old surface, as the new rendering will not adhere to the old unless this is done.

Cutting Pipes for Junctions.—To enable the correct angle to be obtained in cutting drainpipes for junctions, first mark the junction points as seen from a position vertically above, when the pipe is laid over the line of pipe to which it is desired to join it, and at the correct angle to which it is to be joined. The outline of the whole cut round the entire diameter of the pipe may then be obtained by holding the pipe in a tub of water so that the two points marked just touch the surface of the water. If the pipe is held in this position for a short time, that portion which was submerged will be found to be darker on its removal, and the top edge of the dark portion gives the cutting line to form a perfect joint.

Leaking Joints to Vents.—A leak will often be found at the junction of the stoneware right-angle bend and the upright cast-iron vent pipe. Such defective joints should be repaired with neat cement, though the practice of carrying out an outlet vent pipe up a tree is not to be recommended, a permanent post firmly set in a concrete foundation being far more satisfactory. Proprietary jointing compounds are available for this purpose.

Gullys.—Though a cracked gully will be very rarely met with it may happen, and there is no satisfactory method of repair other than its complete removal and renewal. When repairing old drains, however, the solid matter which collects in the trap of a gully should be thoroughly cleaned out.

Removing Stoppage.—However carefully the drains may be laid, with due regard to gradient, satisfactory bends and careful workmanship in the joints, junctions, benchings, etc., carelessness in their use will often cause stoppage. Such insoluble material as pieces of firewood, old rags, matchboxes, candle ends, and in fact almost any household waste products, are thrown into a W.C. pan.

If it is required to trace the lines of piping in the system of old drains before any excavation is undertaken, different-coloured waters poured in at each fitting and manhole separately, the inlet to the manhole or disconnecting chamber, as the case may be, being watched as each different-coloured water is poured through, will provide the required know-

ledge. Potassium permanganate crystals can be used to make a red solution. Whitening makes a suitable white solution. Any ordinary stoppage may be removed with the drain rod, but if the blockage resists all efforts to push it forward, the screw claw should be fitted to the lowest rod and well twisted into the blockage, which may then be withdrawn. In twisting the rods, always turn from left to right, or the screw joint between the sections will be undone.

Force pumps will be required to clean out any stoppage in traps, though a home-made plunger, consisting of a circular piece of wood wrapped round with cloth and jointed at right angles to a handle of convenient length, will prove equal to the removal of any ordinary stoppage.

CHAPTER 10

SEWAGE DISPOSAL AND SEWERS: DRAINAGE BY-LAWS

THE following systems of sewage disposal are in use :

No water flush.—(*a*) Earth closet.
(*b*) Chemical closet.
Water flush.— (*c*) Cesspool on site. (Storage.)
(*d*) Septic tank on site.
Water flush.— (*e*) Drainage by public sewers to sewage-disposal installations.

DRY DISPOSAL

Where water is not available for flushing, the earth closet, privy, or chemical closet may be installed.

Earth Closet.—Dry earth has the power of neutralising fæcal matter. For this purpose a special closet is made consisting of a galvanised-iron receptacle with the usual wood tip-up seat. The receptacle should not exceed 2 cubic feet capacity, and though readily removable for emptying it should be held in the correct position by guides. An earth container is fitted at the back and above the level of the receptacle. The outlet of the earth container makes a loose fit with an inlet near the top of the receptacle. The movement of dry earth from the container to the receptacle is controlled by operating a rod connected to a movable plate at the foot of the container.

The privy or midden, which consists merely of a receptacle for the fæcal matter, and contains no apparatus for deodorising the matter, should not now be in use. It is insanitary and is not authorised by the Public Health Act or the latest By-laws.

By-laws.—The requirements of the Model By-laws, Series IV, Buildings, and the L.C.C. Drainage By-laws may be summarised as follows :

An earth closet must have a direct entrance from the external air.

It must be not less than 40 feet from any well, spring, or stream.

It must have a sufficient opening for lighting and ventilation communicating with the open air.

The floor must be of non-absorbent material, not less than 3 inches above the surface of the adjoining ground, and have a fall towards the entrance doorway of not less than $\frac{1}{2}$ inch to 1 foot. The receptacle must be of non-absorbent material, leak-proof, and not exposed to rain. The

capacity to be not more than 2 cubic feet. The container for the dry earth must be readily accessible and have suitable means of applying the dry earth to the fæcal matter. The receptacle must be readily removable for emptying and cleansing.

The neutralised contents of the receptacle should be spread on and then dug into the ground, for which it makes a good manure.

Chemical Closet.—This consists of a closet container with seat. The fæcal matter is immersed and sterilised in a chemical solution held in the container. The reduced fæcal matter is afterwards disposed of on the land.

Although the chemical closet is classed as an earth closet in by-laws, it is much more convenient and efficient.

There are various types. In some types the container must be removed once a week and emptied on the land. In others there is an outlet which can be connected with drainpipes to a soak-away (in absorbent subsoil).

THE CESSPOOL

A cesspool is a large storage container for fæcal matter. It does not dispose of the sewage and must be periodically emptied. This is now usually done by the local authority.

The cesspool is built below ground level at some distance from the building and any well or spring, and is connected to the sanitary fittings by ordinary drainpipes. Ordinary water-flush closets are used.

The cesspool should be a brick-in-cement-mortar or a cement-concrete tank with a cement-concrete bottom and top slab. The top should be fitted with a cast-iron airtight cover and frame. It must be impervious, and should be either rendered with waterproofed cement mix or the exterior should be puddled with clay. If the cesspool must be emptied by the owner it should be fitted with a chain pump, but local authorities usually empty by means of a vacuum apparatus which draws the fæcal matter into a large steel tank on a motor chassis. For this purpose a flexible pipe is lowered through the opening at the top into the contents.

A cesspool should be of adequate capacity to hold the drained matter and fluids for the period between emptying dates. It should be ventilated with a fresh-air inlet 6 feet above ground level, and a foul-air vent about twice that height.

Cesspools are satisfactory only if periodically emptied by the local authority with vacuum apparatus. Otherwise, a septic-tank installation is much better.

By-laws.—The Ministry of Health and L.C.C. By-laws may be summarised as follows :

The cesspool should be at least 50 feet (in London 100 feet) from any dwelling or other building, and at least 60 feet (in London 100 feet) from any well, spring or stream, the water of which is used for drinking, washing, etc.

THE SEPTIC TANK AND FILTER

The septic tank would be much better named if it were termed a bacterial tank, as this word accurately explains the process upon which its correct functioning depends. Though the terms used, sounding as they do somewhat scientific, may put people off, yet the actual process is very simple, and should be readily understood by anyone.

The principle of this method of treatment of sewage is merely the provision of two receptacles in which the sewage may produce within itself two opposite kinds of bacteria or microbes. These are called anaerobic microbes and aerobic microbes, these two terms meaning nothing more alarming than that the first microbes develop best in an enclosed chamber shut away from the light and air, whilst the second require these in order to grow and function. From this it will be obvious at once that two chambers are required for this plant, one enclosed and sealed up, and the other open to the light and air.

The septic tank therefore consists of an airtight chamber built of brick or concrete, lined with cement rendering, or glazed brick, blue bricks, or other impervious and watertight construction.

This tank is fitted with an inlet drain which is trapped in a ventilated intercepting chamber above the tank and an outlet drain both at approximately the same height and near the top of the tank. The outlet should actually be an inch or so lower than the inlet. Both inlet and outlet pipes should be carried down to within 18 inches of the bottom of the tank. From this description it will be clear that once the tank becomes filled, it will discharge liquid from the outlet whenever and at the same rate as sewage flows into it through the inlet pipe. And as the solid matter in sewage is for the most part lighter than the liquid, this will rise to the surface where it forms a semi-solid scum. The outlet pipe being led up from near the bottom, it follows that the outflow will be liquid, leaving the solids behind at or near the surface.

The sewage, when so confined in an airless chamber from which all light is excluded, breeds microbes which break down the solid matter and split it up into water, carbon dioxide and other gases. Consequently, it is necessary to fix to this tank an outlet vent for these gases.

The microbe or germ which is bred in the dark tank is called the anaerobic microbe. The aerobic microbe, however, requires light and air in order to perform its functions. This is provided to the sewage by the construction of a flat chamber known as the filter bed, in which some porous material, such as charcoal or cinders, is placed; the purpose of these materials being to provide air to the liquid, which they do by retaining it in the holes with which this substance is pierced.

From this it will be gathered that to function properly *a filter bed must be kept as dry as possible.* It would be difficult to stress this necessity too much, as there seems to be an idea prevalent that a filter, or rather the material composing a filter itself, has some power to act upon the

filtrate. This is not so. It is the air in the filtering material that acts upon the filtrate. Consequently, a filter bed must be provided with adequate outlet *at its bottom and never at its top*, as is so often seen. It would be as unreasonable to expect a man to live under water as to expect aerobic germs to breed in a filter bed that is continually in a saturated condition.

The Construction of the Filter Bed is simple. It consists of walls of concrete, or cement-rendered brickwork, on a concrete bottom, and the

Fig. 145.—The right and wrong methods of draining the filter bed.

depth should not exceed 4 feet 6 inches. The tank will function best if it is formed of two compartments side by side, one being in use whilst the other is allowed to dry out. This is effected by running the fluid from the septic tank into a tilting distributor. In order to further distribute the effluent over the surface of the filter bed, there should be perforated channels run at right angles to the tilting distributor into which the filtrate is run from the distributor.

Septic-tank systems for the disposal of large quantities of sewage have

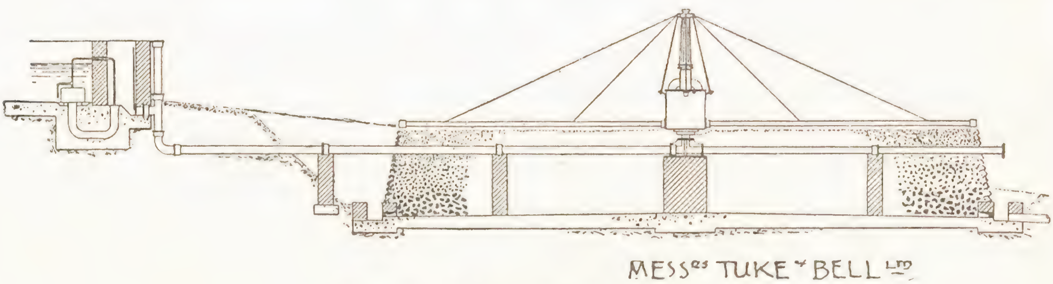


Fig 146.—A large circular filter bed

the filtration beds constructed in circular formation, in which the filtering material is stacked above the tops of the walls of the filter bed, so that the air has direct access not only to the top but to the sides of the filter bed. This affords additional proof of the fact that it is the air in the pores of the filtering material, and not the material itself, which performs the actual filtering operation.

In these large circular filter beds the sprinklers radiate from a centre outlet pipe, like spokes of a wheel, the whole revolving over the surface of the filter bed, thus ensuring that the filtrate is spread over the entire

surface of the bed, and that no part of it becomes sufficiently wetted to drive out the air from the pores of the filtering material. The outlet from the filter bed where there are two or more chambers may be joined together into one line of piping, and then spread out in fan-shaped lines of agricultural drainpipes, so that the liquid may soak away into the subsoil, or be conducted to any convenient watercourse.

A Small Septic Tank (see Fig. 147).—This example is about the minimum size for a small family. The capacity of the septic-tank

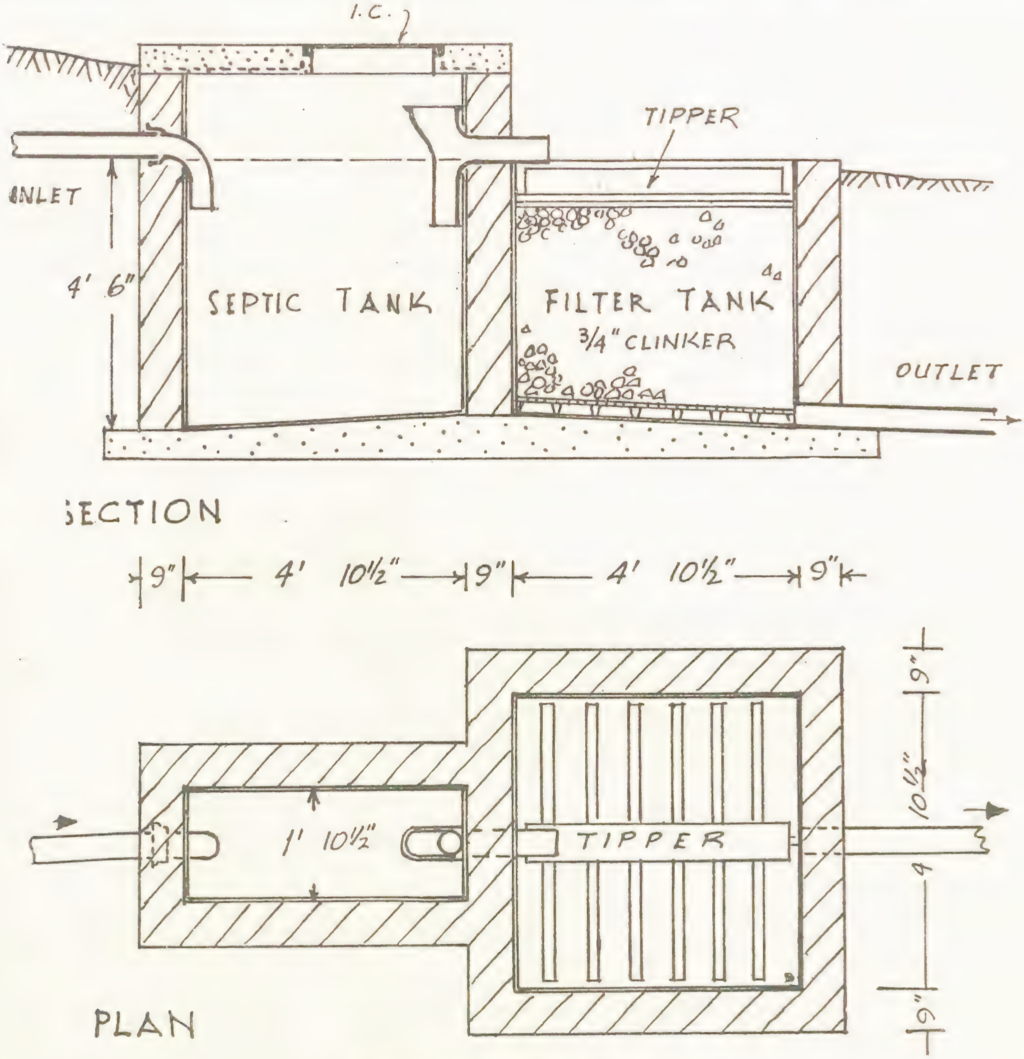


Fig. 147.—A small septic tank.

chamber (below the outlet level) should be about three-quarters of one day's flow of sewage.

There is some risk of solid matter passing from the septic chamber to

the filter through a sudden inrush of water from a bath discharge. To prevent this a baffle of slate should be fixed across the middle of the septic tank with a space a few inches from the floor. Alternatively, the outlet may be fitted with a perforated screen or grating.

It is advisable to place such work with a specialist firm under a guarantee of satisfactory working. The only attention which should be necessary is the cleaning off of scum on the surface (in the septic chamber), about three times a year, and the cleaning out of this chamber to remove sludge from the bottom as necessary.

PUBLIC SEWAGE DISPOSAL

The public sewers collect fæcal matter and waste water and convey the mixed solids and fluids to the disposal works. There are several systems of rendering the sewage harmless and disposing of it.

In some systems the sewage is spread over porous land in such a manner that it is liquefied and soaks into the land. This manures the land, which is periodically used for growing crops. This is called irrigation.

Another method is by filtration through a light absorbent land, the purified liquid passing through subsoil drains into rivers or streams.

Precipitation is now largely used. This consists of the treatment of sewage by certain chemicals. A harmless sludge results which can be compressed and used as a manure on the land, or disposed of by carrying it out to sea.

Bacteriolysis, as described under Septic Tanks, is made use of in the filtration plants of sewage-disposal systems.

Surface Water.—Rainwater from roofs, paved yards, and road surfaces is sometimes drained into a separate surface-water sewer and disposed of by connecting it to a river or stream. Some authorities compel building owners to have at least half the roof and yard water drained into the surface-water sewer. Owing to the high cost of double drains and sewers, this system is not widely used.

BY-LAWS RESPECTING W.C.S AND EARTH CLOSETS

The following By-laws made by the L.C.C. refer to water-closets, earth closets, cesspools, etc.:

"**2. *Water-closets.***—A builder constructing a water-closet in connection with a building shall comply with the following requirements:

"(1) *Situation.*—Such water-closet shall be so situated that at least one of its sides shall be an external wall, which shall be in conformity with the following conditions:

"(*a*) If the water-closet is so situated that the surface of the floor

is at or above or not more than 5 feet below the ground level such external wall shall abut immediately upon :

" (i) A street ; the surface of which shall be at a level not exceeding 5 feet above the level of the floor of the water-closet, or

" (ii) An open space dedicated to the public or permanently secured to the building in connection with which the water-closet is provided with a surface area of not less than 100 square feet measured horizontally at a level not exceeding 5 feet above the level of the floor of the water-closet and a minimum width of 3 feet if enclosed on not more than two sides and 7 feet if enclosed on every side.

" (*b*) If the water-closet is so situated that the surface of the floor is more than 5 feet below the ground level, such external wall shall abut upon an area or open space permanently secured to the building in connection with which the water-closet is provided, not covered in otherwise than by a suitable grating, and having a minimum horizontal superficial area of 40 square feet and a minimum width of 5 feet or, where such area or open space is restricted to lighting and ventilating the water-closet, measuring horizontally not less than 5 feet × 5 feet. Such area or open space shall immediately abut upon, and the surface of such area or open space shall be not more than 12 feet below, a street, a forecourt immediately adjoining a street, or an open space as hereinbefore prescribed in paragraph (*a*) (ii).

" Provided always :

" (i) That where the water-closet does not exceed 20 feet in height or the height of the storey in which the water-closet is situated the water-closet may be so situated as not to have an external wall if a street or an open space as hereinbefore prescribed in paragraph (*a*) is available at the level of and abutting on the roof of the water-closet.

" (ii) That the water-closet may be so situated that none of its sides is an external wall and that an open space as hereinbefore described in paragraphs (*a*) or (*b*) need not be provided if means of artificial lighting and a system of mechanical ventilation are furnished to such water-closet in accordance with paragraph (4) (*e*) of this by-law.

" (2) *Entrance and Entrance Lobby.*—Such water-closet shall not be situated within nor entered from any room used for human habitation, or as a scullery, schoolroom, office, factory, workshop, workplace, or for the manufacture, preparation, storage or sale of food or drink for man, or as a public room, except through the external air or an intervening entrance lobby.

" The entrance lobby shall be constructed of solid and suitable materials so as to secure aerial disconnection between such water-closet and any

room specified in the foregoing paragraph of this by-law, and such lobby shall be :

" (*a*) Provided with close-fitting and self-closing doors.

" (*b*) Adequately lighted and ventilated.

" Provided always that a water-closet used exclusively with a bedroom or dressing-room may be entered directly from such room.

(3) *Form of Construction.*—Such water-closet shall :

" (*a*) If situated wholly or partly within a building be :—

" (i) Properly ceiled.

" (ii) Enclosed by solid walls or partitions of brick, concrete, or other suitable material, and every such wall or partition shall, where abutting upon any room specified in paragraph (2) of this by-law, be finished with an impervious surface towards the water-closet.

" (*b*) If not situated wholly or partly within a building be :

" (i) Constructed of brick, concrete, or other suitable material, with any wall abutting upon any room specified in paragraph (2) of this by-law finished with an impervious surface towards the water-closet.

" (ii) Covered with a properly constructed roof provided with suitable means for discharging rain-water therefrom.

" (*c*) Where entered directly from the external air be paved with hard and impervious material laid to a suitable fall and finished with a smooth surface at least 3 inches above the level of the street or area or open space from which it is entered.

" (*d*) Be provided with a proper entrance door and fastenings.

" (4) *Lighting and Ventilation.*—Such water-closet shall :

" (*a*) If an external wall is provided, and if such water-closet contains a single soil-pan or basin only, have :

" (i) In such external wall a suitable window of an area exclusive of the frame of not less than 2 square feet, of which window an area of at least half shall open.

" (ii) An air-brick, air-shaft, or other adequate means of constant ventilation.

" (*b*) If an external wall is provided, and if such water-closet contains two or more soil-pans or basins, have :

" (i) In such external wall a suitable window or windows of a total area exclusive of the frame or frames of not less than one-fifth of the floor space, of which window or windows an area of at least half shall open.

" (ii) One or more air-bricks, air-shafts, or other adequate means of constant ventilation, with a total unobstructed sectional area of not less than twenty square inches per soil-pan or basin, in a suitable position or positions.

" (*c*) If not provided with an external wall but provided with an

open space as prescribed by paragraph (1) (*a*) and proviso (i) to paragraph (1) of this by-law have means of lighting and ventilation in the form of :

"(i) A suitable glazed lantern light or skylight of an area exclusive of the frame of not less than one-fifth of the floor space with louvred or other suitable openings equal to at least one-tenth of the floor space.

"(ii) One or more air-shafts or other adequate means of constant ventilation, with a total unobstructed sectional area of not less than 20 square inches per soil-pan or basin, in a suitable position or positions.

" Provided always that such water-closet, if situated under a public footpath where the provision of a lantern light or skylight for lighting and ventilation is, for such reason, impracticable, shall have :

"(i) Means of lighting in the form of a pavement or other similar light of equal area to that hereinbefore prescribed in paragraph (*c*) (i) for a lantern light or skylight.

" (ii) Means of ventilation in the form of suitable inlet and outlet air-shafts, the outlet shaft being fitted with a suitable exhaust fan.

"(*d*) If aerially disconnected from all buildings occupied by any person and directly approached from the external air, have means of lighting and ventilation as prescribed in either of the foregoing paragraphs (*a*), (*b*) or (*c*), or other equally effectual means.

" (*e*) If so situated that none of its sides is an external wall and an open space is not provided, have suitable means of artificial lighting and a suitable system of mechanical ventilation complying with the following requirements :

"(i) The system of ventilation shall be separate and distinct from any system of ventilation installed for any other purpose.

"(ii) A sufficient number of suitably placed fresh-air inlets shall be provided.

"(iii) The fan and motor or other mechanical means shall be in duplicate and capable of extracting air from the water-closet at a minimum rate of 750 cubic feet per hour per soil-pan or basin. The aerial content of the water-closet shall be changed at least three times per hour.

"(5) *Materials, Form of Construction and Trapping of Soil-pan or Basin.*—Such water-closet shall be furnished with a suitable soil-pan or basin :

"(*a*) Constructed of glazed earthenware, enamelled fireclay, or other equally suitable material.

"(*b*) Fitted with a flushing rim.

"(*c*) Of such shape, capacity and mode of construction as to receive and contain a sufficient quantity of water to cover the filth

which may be deposited in such soil-pan or basin and to allow all such filth to fall free of the sides thereof and directly into the water.

"(*d*) Provided with a suitable and efficient trap[1]:

"(i) Constructed of lead, copper, cast-iron, glazed earthenware, enamelled fireclay, or other equally suitable material, with an exposed and accessible outgo or outlet for connecting to a soil pipe or drain.

"(ii) Fixed immediately beneath such soil-pan or basin.

"(*e*) Furnished, except in the case of an Eastern fitment (siege turque), with suitable seat rims or insets or a hinged seat.

"(6) *Flushing Cistern and Apparatus.*—Such water-closet shall be provided with a suitable flushing cistern for the purpose of cleansing such soil-pan or basin and such cistern shall be so constructed, fitted, placed and supplied as to comply with the following requirements:

"(*a*) It shall be separate and distinct from any cistern used for drinking water.

"(*b*) The discharging or flushing capacity shall not be less than two gallons of water.[2]

"(*c*) It shall be fitted with:

"(i) A ball-valve so arranged as to re-fill the cistern with water within a period not exceeding two minutes after the cistern is operated.

"(ii) A suitable apparatus for the effectual application of water to and the effectual cleansing of such soil-pan or basin and for effecting the prompt removal therefrom and from the trap connected therewith of any solid or liquid filth which may be deposited therein.

"(iii) A flush pipe constructed of lead, copper, iron, or other equally suitable material connected to the cistern and to the flushing rim of the soil-pan or basin by a union or other equally suitable form of connection and having throughout an internal diameter of not less than $1\frac{1}{4}$ inch.

"Provided always:

"(i) That there shall not be any direct connection between any water-service pipe upon the premises and any part of the soil-pan or basin.

"(ii) That where the water for flushing purposes is obtained from a private well or other source having no connection with the mains of a statutory water authority the requirement relat-

"[1] In addition to the requirements here enumerated, a trap must conform with by-law No. 5 (12) made under section 202 of the Metropolis Management Act, 1855, and the Metropolis Management Acts Amendment (By-laws) Act, 1899, in respect of the water seal."

"[2] The flushing capacity here required is the maximum flush prescribed by 'Regulations made under the Metropolis Water Act, 1871.' These Regulations further prescribe that no alterations shall be made in any fittings in connection with the supply of water by the Metropolitan Water Board without two days' previous notice in writing to the Board."

ing to the provision of a flushing cistern shall be deemed to be complied with in any case where the soil-pan or basin is connected with an effectual flushing valve supplied with water from a storage cistern of adequate capacity used solely for the purpose of flushing water-closets, slop sinks or urinals, and complying in all other respects with the foregoing paragraphs (*b*), (*c*) (ii) and (iii).

"(7) For the purposes of this by-law a compartment containing two or more soil-pans or basins separated by partitions shall be deemed to be two or more water-closets, unless the partitions do not exceed 7 feet in height and have a space of at least 6 inches between the tops and bottoms of such partitions and the ceiling and floor respectively.

"**3. *Urinals.***—A builder constructing a urinal in connection with a building shall comply with the following requirements:

"(1) *Situation, Entrance and Entrance Lobby, Form of Construction, Lighting and Ventilation.*—Such urinal shall comply with the requirements contained in paragraphs (1), (2), (3) and (4) of the preceding by-law No. 2 for which purpose it shall be deemed to be a water-closet.

"Provided always that the fan and motor or other mechanical means described in paragraph (4) (*e*) (iii) of by-law No. 2 shall be capable of extracting air from the urinal at a minimum rate of 750 cubic feet per hour per urinal basin, or each width or length not exceeding 2 feet 3 inches of stall or trough respectively, and that the aerial content of the urinal shall be changed at least three times per hour.

"(2) *Materials, Form of Construction and Flushing of a Urinal Basin, Stall or Trough.*—Such urinal shall be provided with:

"(*a*) A basin, stall or trough constructed of glazed stoneware, glazed earthenware, enamelled fireclay or other equally suitable material of such shape as will facilitate maintenance in a state of cleanliness.

"(*b*) A suitable flushing cistern so constructed, fitted, placed and supplied that:

"(i) It shall be separate and distinct from any cistern used for drinking-water.

"(ii) The discharging or flushing capacity shall not be less than one gallon of water [1] for each connected basin, or each width or length not exceeding 2 feet 3 inches of stall or trough respectively.

"(iii) It shall be capable of being filled or charged with water within a period not exceeding twenty-five minutes or

"[1] The flushing capacity here required is the maximum flush prescribed by 'Regulations made under the Metropolis Water Act, 1871.' These Regulations further prescribe that no alterations shall be made in any fittings in connection with the supply of water by the Metropolitan Water Board without two days' previous notice in writing to the Board."

such less period as will permit, while the urinal is in use or available for use, a flushing operation of sufficient frequency to ensure the maintenance of such basin, stall or trough in a state of cleanliness.

"(iv) It shall be fitted with a suitable automatic discharging apparatus connected to the urinal basin, stall or trough by an adequate flush pipe or pipes of lead, copper, iron, or other equally suitable material having a minimum internal diameter of ½ inch and fitted with a suitable spreader or sparge pipe so as effectually to distribute the water over the internal surface of every basin, stall or trough.

"Provided always:

"(i) That there shall not be any direct connection between any water-service pipe upon the premises and any part of a urinal basin, stall or trough.

"(ii) That where the water for flushing purposes is obtained from a private well or other source having no connection with the mains of a statutory water authority, the requirement relating to the provision of a flushing cistern shall be deemed to be complied with in any case where the urinal basin, stall or trough is connected with an effectual flushing valve supplied with water from a storage cistern of adequate capacity used solely for the purpose of flushing water-closets, slop sinks or urinals, and complying in all other respects with the foregoing paragraphs (*b*) (ii), (iii) and (iv).

"**4. *Earth-closets.***—A builder constructing an earth-closet in connection with a building shall comply with the following requirements:

"(1) *Situation.*—Such earth-closet shall be so situated that at least two of its sides shall be external walls, which walls shall abut immediately upon a street, or upon an open space as prescribed in by-law No. 2 (1) (*a*) (ii) for a water-closet, but with the surface of such street or open space measured horizontally at a level of at least 3 inches below the level of the floor of such earth-closet.

"(2) *Entrance.*—Such earth-closet shall be entered directly from the external air.

"(3) *Form of Construction.*—Such earth-closet shall:

"(*a*) If situated wholly or partly within a building be constructed in accordance with the requirements contained in by-law No. 2 (3) (*a*) and (*d*) for a water-closet.

"(*b*) If not situated wholly or partly within a building be constructed in accordance with the requirements contained in by-law No. 2 (3) (*b*) and (*d*) for a water-closet.

"(*c*) Be suitably paved throughout with hard, jointless and impervious material finished with a smooth surface not less than 3 inches above the surface of the adjoining ground and with a sufficient fall to the door of such earth-closet.

"(*d*) Be provided with a space beneath the seat prescribed in paragraph (5) (*a*) of this by-law constructed :

"(i) Of sufficient dimensions to admit of the receptacle prescribed in paragraph (5) (*b*) of this by-law being so placed and fitted as effectually to prevent the deposit of any filth elsewhere than in such receptacle and to allow of the effectual application of dry earth or other deodorising substance to any filth in such receptacle.

"(ii) With adequate means of access for cleansing such space and for placing therein and removing therefrom the receptacle for filth.

"(iii) With the surface of the containing walls of such space rendered with hard and impervious material finished with a smooth surface ; and any woodwork abutting upon such space so coated or treated as to be impervious to moisture.

"(*e*) Be so constructed that :

"(i) The contents of the receptacles for filth and dry earth or other deodorising substance prescribed in paragraph (5) of this by-law shall be protected from any rainfall and any waste water or liquid refuse from any premises.

"(ii) No part of such earth-closet nor any receptacle therein shall communicate with any drain.

"(4) *Lighting and Ventilation.*—Such earth-closet shall be provided with a sufficient opening for light and ventilation as near to the top as practicable and communicating directly with the external air.

"(5) *Provision of Seat, Receptacles for Filth and Dry Earth, and Apparatus.*—Such earth-closet shall be provided with :

"(*a*) A suitable hinged seat fitted with a urine guide.

"(*b*) A movable receptacle of a capacity not exceeding 2 cubic feet, constructed of galvanised iron or other equally suitable material, for the reception of filth.

"(*c*) A suitably constructed receptacle of adequate capacity so placed as to admit of ready access for depositing therein a supply of dry earth or other deodorising substance and fitted with suitable means or apparatus for the effectual application of a sufficient quantity of dry earth or other deodorising substance to any filth deposited in the receptacle for filth.

"**5. *Privies.***—A builder constructing a privy in connection with a building shall comply with the following requirements :

"(1) *Situation.*—Such privy shall be situated :

"(*a*) Twenty feet at least from any public room, any school, any dwelling house, and any building in which any person may be or may be intended to be employed in any manufacture, trade or business.

" (*b*) One hundred feet at least from any well, spring, or stream of water used or likely to be used by man for drinking or domestic purposes, and in such a position as will not render any such water liable to pollution.

" (*c*) In such a position and manner as to afford ready means of access for the purpose of cleansing such privy and of removing filth therefrom without such filth being carried through any public room, or school, or dwelling house, or any building in which any person may be or may be intended to be employed in any manufacture, trade or business, or any building used for the storage of food or drink for man.

" (2) *Form of Construction.*—Such privy shall be :

" (*a*) Constructed of brick, concrete or other suitable material and covered with a properly constructed roof provided with suitable means for discharging rain-water therefrom.

" (*b*) Provided with a space beneath the seat prescribed in paragraph (4) (*a*) of this by-law constructed :

" (i) Of sufficient dimensions to admit of the receptacle for filth prescribed in paragraph (4) (*b*) of this by-law being so placed and fitted as effectually to prevent the deposit of any filth elsewhere than in such receptacle.

" (ii) With walls of brick, concrete, or other suitable material of adequate thickness rendered with hard and impervious material finished with a smooth surface; a riser of flagging, slate, rendered brickwork, or other suitable hard and impervious material finished with a smooth surface ; and any woodwork abutting upon such space so coated or treated as to be impervious to moisture.

" (iii) With a door in the back or one of the sides of such privy capable of being opened from the outside of such privy for the purpose of cleansing such place and removing therefrom or placing or fitting therein the receptacle for filth.

" Provided always that in any case where the provision of such door is impracticable, the foregoing requirement shall be deemed to be complied with if the whole of such seat or a sufficient part thereof is so arranged and fitted as to afford adequate means for access and cleansing.

" (*c*) Suitably paved with hard, jointless and impervious material finished with a smooth surface with the surface of the portion in front of the seat prescribed in paragraph (4) (*a*) of this by-law not less than 6 inches and the space beneath such seat not less than 3 inches respectively above the surface of the adjoining ground and with suitable falls to the doors of such privy.

" (*d*) Provided with a proper entrance door and fastenings.

" (*e*) So constructed that :

" (i) The contents of the receptacle for filth shall be protected

from any rainfall and any waste water or liquid refuse from any premises.

"(ii) No part of such privy nor any receptacle therein shall communicate with any drain.

"(3) *Lighting and Ventilation.*—Such privy shall be provided with means of lighting and ventilation in accordance with the requirements contained in by-law No. 4 (4) for an earth-closet.

"(4) *Provision of Seat and Receptacle for Filth.*—Such privy shall be provided with:

"(*a*) A suitable hinged seat fitted with a urine guide.

"(*b*) A movable receptacle of a capacity not exceeding 2 cubic feet, constructed of galvanised iron or other equally suitable material, for the reception of filth.

"**6. *Cesspools.***—A builder constructing a cesspool in connection with a building shall comply with the following requirements:

"(1) *Situation.*—Such cesspool shall be situated:

"(*a*) One hundred feet at least from any public room, any school, any dwelling house, any building in which any person may be or may be intended to be employed in any manufacture, trade or business, and any well, spring, or stream of water.

"(*b*) In such a position as to afford ready means of access for the purpose of emptying and cleansing such cesspool and for removing the contents therefrom without being carried through any public room, or school, or dwelling house, or any building in which any person may be or may be intended to be employed in any manufacture, trade or business, or any building used for the storage of food or drink for man.

"(2) *Form of Construction.*—Such cesspool shall be:

"(*a*) Constructed of concrete, or good brickwork bedded and grouted in cement and rendered on the inside surface with cement, with walls and floor at least 9 inches in thickness, or otherwise constructed of suitable materials, and so as to be watertight.

"(*b*) Arched or otherwise properly covered over and provided with means of access furnished with a suitable airtight cover.

"(*c*) Provided with adequate means of ventilation.

"(*d*) So constructed as not to communicate with any sewer.

"**7. *Number of Water-closets, etc., to be Provided.***—The owner of any occupied building shall provide and maintain in connection with such building, water-closet, earth-closet, or privy accommodation in the proportion of not less than one water-closet, earth-closet, or privy for every 12 inmates of such building.

"**8. *Alteration, Reconstruction and Repair.***—No alteration, partial or entire reconstruction, or repair of any water-closet, urinal, earth-

closet, privy, or cesspool, constructed in accordance with these by-laws shall be made so that by reason of such alteration, partial or entire reconstruction, or repair any such water-closet, urinal, earth-closet, privy or cesspool, will not be in conformity with these by-laws.

"The alteration, partial or entire reconstruction, or repair of any water-closet, urinal, earth-closet, privy, cesspool, shall, so far as practicable, be carried out so as to comply with these by-laws in respect of such alteration, partial or entire reconstruction, or repair.

"**9.** ***Notice of Work.***—Every builder who is about to execute any work as defined in these by-laws shall serve upon the Sanitary Authority of the district, at their office, at least 24 hours' notice in writing of the day and time at which such work is to be commenced, together with such detailed description as shall sufficiently describe the proposed work.

"**10.** ***Maintenance in State of Repair, etc.***—(1) The owner of any premises shall at all times maintain in a proper state of repair and in proper working order every water-closet, urinal, earth-closet, privy, or cesspool, and the accessories thereof belonging to such premises, and he shall at all times keep and maintain in conformity with these by-laws every water-closet, urinal, earth-closet, privy, or cesspool, and the accessories thereof constructed in accordance with these by-laws.

"(2) The occupier of any premises where the floor of a water-closet belonging to such premises is not constructed of or paved with hard and impervious material finished with a smooth surface shall cause such floor to be covered and kept covered with smooth and impervious material.

"(3) The occupier of any premises shall cause every water-closet, urinal, earth-closet, privy and accessory thereof belonging to such premises to be thoroughly cleansed from time to time as often as may be necessary for the purpose of keeping such water-closet, urinal, earth-closet, privy and accessory thereof in a cleanly condition.

"(4) The landlord or occupier of any premises wherein a system of mechanical ventilation is furnished to any water-closet or urinal in accordance with by-law No. 2 (4) (*e*) or by-law No. 3 (1) shall cause such system to be continuously used and operated while the premises are occupied.

"(5) The occupier of any premises shall at all times maintain in the receptacle provided for such purpose in connection with any earth-closet belonging to such premises a sufficient quantity of dry earth or other deodorising substance.

"Provided always that where two or more occupiers of an occupied building are entitled to the use in common of any water-closet, urinal, earth-closet or privy the landlord shall cause such water-closet, urinal, earth-closet, or privy to be cleansed as aforesaid, and shall maintain in connection with such earth-closet a sufficient quantity of dry earth or other deodorising substance in the receptacle provided for such purpose."

DRAINAGE BY-LAWS

Drainage By-laws[1] *made by the London County Council on 6th March,* 1934, *under Section* 202 *of the Metropolis Management Act,* 1855, *and the Metropolis Management Acts Amendment (Byelaws) Act,* 1899, *and confirmed by the London County Council on* 14*th March,* 1934.

"**1.** ***Interpretation of Terms.***—In these by-laws, unless the context otherwise requires :

" 'Drainage work ' means any pipe, drain, or other means of communicating with sewers and any trap or apparatus connected therewith.

" 'Subsoil drain ' means a drain used or constructed to be used solely for conveying to any sewer (either directly or through another drain) any water that may percolate through the subsoil.

" 'Surface-water drain ' means a drain used or constructed to be used solely for conveying to any sewer (either directly or through another drain) any rain water from roofs or from ground surfaces whether paved or unpaved, but does not include a rain-water pipe.

" 'Rain-water pipe ' means a pipe or drain situate wholly above ground and used or constructed to be used solely for carrying off rain water directly from roof surfaces.

" 'Sewage drain ' means a drain used or constructed to be used for conveying solid or liquid waste matters to a sewer.

" 'Slop sink ' means a sink constructed or adapted to be used for receiving solid or liquid excremental matter.

" 'Soil fitment ' means a water-closet, slop sink, or a urinal.

" 'Waste-water fitment ' means a bath, lavatory basin, bidet, or a sink other than a slop sink.

" 'Concrete ' means a conglomerate of clean gravel, hard brick broken small, or other equally suitable aggregate, with a sufficient quantity of clean sand, well mixed with cement in the proportion of not less than one part by measure of cement to eight parts of other material.

" 'Cement ' means good Portland or other suitable cement of at least equal quality.

" 'Sanitary authority ' means the Council of the Metropolitan Borough in which any drainage work has been, is being or is about to be executed.

" 'Builder ' means the builder, contractor or person actually executing any drainage work, and for the purpose of the by-law No. 14 relating to the deposit of plans, sections, and particulars, means the builder, contractor or person intending actually to execute such work, but does not include a workman in the employ of such builder, contractor or person, and where, after written request by the sanitary authority, the owner or occupier of any premises on which any drainage work has been or is being executed fails to furnish such authority with the name and address of such builder, contractor or person, includes such owner or occupier.

" **2.** ***Subsoil Drains.***—(1) A subsoil drain shall not be connected directly with a sewage drain, or sewer, or a surface-water drain communicating with a sewage drain or sewer without the intervention of a suitable trap between such subsoil drain and such sewage drain, or sewer, or surface-water drain.

" (2) A ventilating opening shall be provided to such subsoil drain as near as may be practicable to such trap, and shall communicate directly with the open air.

" (3) Such trap and the drain between such trap and such sewage drain, or sewer, or surface-water drain, shall be constructed in the manner prescribed in by-law No. 5 for sewage drains.

" (4) The subsoil drain above such trap shall :

" (*a*) Be formed of earthenware field or other suitable pipes.

" (*b*) Be properly laid to an adequate fall.

" (*c*) Discharge into such trap.

" **3.** ***Surface-water Drains.***—A surface-water drain shall be constructed in the manner prescribed in by-law No. 5 for sewage drains.

" Provided always :

" (*a*) That such drain may have an internal diameter of less than 4 inches.

" (*b*) That where such drain is intercepted from a sewage drain or sewer by a suitable trap communicating directly with the open air and furnished with adequate means of access :

" (i) If the inlet to such drain is not less than 10 feet distant from any building, the inlet may be in the form of an untrapped gully with adequate provision for catching sand or other detritus and covered with a grating, the bars of which shall be not more than $\frac{3}{8}$ inch apart.

" (ii) If such drain receives only rain water from roofs, the inlet to such drain may be in the form of a rain-water shoe, or an untrapped gully as prescribed in the foregoing paragraph (i).

" **4.** ***Rain-water Pipes.***—A rain-water pipe conveying to a sewer any rain water shall discharge directly or by means of a channel into or over an inlet to :

" (*a*) A surface-water drain, or

" (*b*) A sewage drain.

" Provided always :

" (i) That where the inlet to such drain is in the form of a properly-trapped gully or other suitable trap such pipe or channel shall discharge above the level of the water in such gully or trap.

" (ii) That a rain-water pipe shall not discharge into or connect with any soil pipe or soil ventilating pipe, or any waste pipe or waste ventilating pipe connected as described in by-law No. 10 (2).

"**5. *Sewage Drains.***—(1) *Materials.*—A sewage drain shall be constructed of good sound pipes formed of cast-iron, glazed stoneware, or other equally suitable material.

"(2) *Cast-iron Pipes, etc.*—If the pipes, traps and fittings are constructed of cast-iron, they shall be effectually protected against corrosion by being coated on both the inside and the outside with Dr. Angus Smith's solution, or other equally suitable solution, or by treatment in some other equally suitable manner, and the thickness of the pipes, traps and fittings, the weight of the pipes, the internal depth of the sockets, and the caulking space shall be in conformity with Table No. I in the schedule to these by-laws.

"(3) *Stoneware Pipes, etc.*—If the pipes, traps and fittings are constructed of stoneware, they shall be of first quality properly glazed, and the thickness of the pipes, traps and fittings, the internal depth of the sockets, and the jointing space shall be in conformity with Table No. II in the schedule to these by-laws.

"(4) *Size, Fall and Line of Drain.*—Every such drain shall :

"(*a*) Be of suitable size with a minimum internal diameter of 4 inches.

"(*b*) Be laid with a suitable fall, and, where practicable, in a direct line.

"(5) *Joints of Drain.*—Every joint in such drain shall be made in the manner and with the jointing materials hereinafter prescribed or otherwise in an equally suitable and efficient manner and with equally suitable materials, and so as to preserve the continuity of the drain without obstruction, namely, if such drain be constructed of :

"(*a*) Cast-iron socketed pipes, the joints shall be made with a gasket of hemp or yarn and metallic lead properly caulked.

"(*b*) Cast-iron flanged pipes, the joints shall be securely bolted together with some suitable insertion.

"(*c*) Stoneware pipes, or pipes of material other than metal, such pipes shall be jointed with socket joints properly put together with a gasket of hemp or yarn and cement or other equally suitable materials.

"(6) *Drain to be Laid on Concrete.*—Such drain shall be laid on a bed of concrete not less than 6 inches thick and projecting on each side of the drain to a width not less than 6 inches.

"Provided always that if any such drain is constructed of cast-iron pipes above the ground and carried at least at each joint on adequate piers or other sufficient supports, the requirements of this paragraph shall not apply.

"(7) *Concrete to be Filled in.*—Concrete shall be filled in so that it shall extend to the full width of the concrete bed prescribed in the foregoing paragraph No. (6), and shall be haunched up to not less than half the external diameter of the pipe.

"(8) *Junctions.*—Every branch drain shall join another drain obliquely in the direction of the flow of such drain and as near as practicable to the invert thereof.

"(9) *Drains within or under Buildings.*—(*a*) A sewage drain shall not be constructed so as to be within or under any building, except in any case where any other situation is impracticable.

"(*b*) Where any such drain or part thereof is constructed within or under a building, such drain or such part thereof shall:

"(i) Be laid or fixed in a direct line where practicable, and be provided with adequate means of access.

"(ii) If constructed of stoneware pipes, be laid on a bed of concrete as prescribed in the foregoing paragraph No. (6) and encased in concrete at least 6 inches thick.

"(iii) If constructed of cast-iron pipes, be laid on a bed of concrete, and filled in and haunched up with concrete as prescribed in the foregoing paragraphs Nos. (6) and (7).

"Provided always that if any such drain constructed of cast-iron pipes be above the ground and carried at least at each joint on adequate piers or other sufficient supports, requirement (iii) shall not apply.

"(10) *Protection to Drain beneath Wall.*—Where any such drain is laid beneath a wall, it shall be protected at the part beneath the wall by means of a relieving arch, or other support, which shall not bear on the drain.

"(11) *Inlets to Drains within Buildings.*—Such drain shall not be constructed in such a manner that there shall be within a building any inlet to such drain except such inlet as may be necessary from any soil fitment, or any waste-water fitment connected directly to such drain.

"Provided always that a drain inlet other than those above-mentioned may be provided within a building if an external position is impracticable; in which case such inlet shall be trapped by a suitable and efficient trap, as hereinafter prescribed in paragraph (12) of this by-law, fitted with a suitable cover and provided where necessary with adequate means of ventilation to the external air.

"(12) *Inlets to Drains to be Trapped.*—Every inlet, other than a ventilating pipe, to such drain shall be properly trapped by a suitable and efficient trap, and such trap shall be formed and fixed so as to be capable of maintaining a water seal of:

"(*a*) Two inches where such inlet has an internal diameter of not less than 3 inches.

"(*b*) Three inches where such inlet has an internal diameter of less than 3 inches.

"(13) *Gratings to Trapped Gullies.*—Every trapped gully shall be covered with a grating, the bars of which shall be not more than $\frac{3}{8}$ inch apart.

"(14) *Trapping of Drains from Sewer.*—(*a*) If an intercepting trap[1] is provided to such drain, such trap shall be:

"(i) Suitable and efficient.

"(ii) Provided with a raking or clearing arm fitted with a secure and suitable stopper as a means of access to the drain between such trap and the sewer.

"(iii) Formed and fixed so as to be capable of maintaining a water seal of at least 2 inches.

"(iv) Fixed at a point in such drain as near as may be practicable to the connection of such drain with the sewer.

"(v) Provided with a manhole or other means of access sufficient for the purposes of clearing.

"(*b*) If an intercepting trap is not provided to such drain any portion of such drain which may be within or under a building shall be constructed of cast-iron.

"(15) *Drain to be Water-tight.*—Such drain shall be constructed so as to be water-tight and to be capable of resisting a pressure of 5 feet head of water.

"(16) *Means of Access.*—Such drain shall be provided with adequate means of access, and every means of access shall be:

"(*a*) Constructed so as to be water-tight.

"(*b*) Fitted with a suitable cover at the level of the adjoining ground surface.

"Provided always:

"(i) That if such means of access is constructed within or under a building, or to a drain to which an intercepting trap has not been provided, it shall be furnished with a suitable screwed or bolted air-tight cover, and where the means of access is in the form of a manhole, such cover shall be fixed to the channel of the manhole and be in addition to the cover at the level of the adjoining ground surface prescribed in the foregoing paragraph (*b*).

"(ii) That where the means of access is in the form of a manhole having a drain or channel fitted with an air-tight cover such manhole need not be water-tight.

"(17) *Ventilation of Drains.*—For the purpose of securing efficient ventilation of such drain the following requirements shall be complied with:

"(*a*) *Ventilating Pipes.*—(i) If an intercepting trap is provided, at least two ventilating pipes shall be provided, one connected to the drain at a point as near as practicable to and on the inlet side of the intercepting trap, and the other at a point as far distant as practicable from the intercepting trap.

"(ii) If an intercepting trap is not provided, at least one ventilat-

"[1] The Metropolis Management Act, 1855, and the London County Council (General Powers) Act, 1920, empower the sanitary authority to require the provision of an intercepting trap wherever they think fit."

water-tight and to be capable of resisting a pressure of 5 feet head of water.

"7. ***Connections of Soil Pipes, Soil Ventilating Pipes, Traps and Drains.***—The connection of the trap of any soil fitment with a soil pipe, ventilating pipe or drain, or the connection of any soil pipe or ventilating pipe with a drain, shall be made in the manner and with the jointing materials hereinafter prescribed or otherwise in an equally suitable and efficient manner, and with equally suitable materials, and so as to preserve the continuity of the trap, pipe or drain without obstruction, namely:

"(*a*) The connection of a lead trap with a lead pipe shall be by a burned, or plumber's wiped soldered joint.

"(*b*) The connection of a lead pipe or trap with a copper pipe or trap shall be by a plumber's wiped soldered joint.

"(*c*) The connection of a lead pipe or trap with an iron pipe, trap or drain, shall be by means of a thimble or flanged ferrule of copper, brass or other suitable alloy connected with the lead pipe or trap by a plumber's wiped soldered joint, and with the iron pipe, trap or drain by a joint made with a gasket of hemp or yarn and metallic lead properly caulked, a screwed joint with a galvanised shouldered cast-iron, wrought-iron or malleable-iron socket, or galvanised cast-iron, wrought-iron or malleable-iron flange union or flanges securely bolted together with some suitable insertion.

"(*d*) The connection of a lead pipe or trap with a stoneware pipe, trap or drain, shall be by means of a thimble or ferrule as described in (*c*) connected with the lead pipe or trap by a plumber's wiped soldered joint and with the stoneware pipe, trap or drain by a joint made with a gasket of hemp or yarn and cement.

"(*e*) The connection of a copper trap with a copper pipe shall be by means of a union nut or flanged coupling.

"(*f*) The connection of a copper pipe or trap with an iron pipe, trap or drain shall be by means of a thimble or flanged ferrule of copper, brass or other suitable alloy connected with the copper pipe or trap by a union nut or flanged coupling, and with the iron pipe, trap or drain by a joint made with a gasket of hemp or yarn and metallic lead properly caulked, a screwed joint with a galvanised shouldered cast-iron, wrought-iron or malleable-iron socket, or galvanised cast-iron, wrought-iron or malleable-iron flange union or flanges securely bolted together with some suitable insertion.

"(*g*) The connection of a copper pipe or trap with a stoneware pipe, trap or drain shall be by means of a thimble or ferrule as described in (*f*) connected with the copper pipe or trap by a union nut or flanged coupling, and with the stoneware pipe, trap or drain by a joint made with a gasket of hemp or yarn and cement.

"(*h*) The connection of an iron pipe or drain with an iron trap shall be by a joint made with a gasket of hemp or yarn and metallic

lead properly caulked, a screwed joint with a galvanised shouldered cast-iron, wrought-iron or malleable-iron socket, or galvanised cast-iron, wrought-iron or malleable-iron flange union or flanges securely bolted together with some suitable insertion.

"(*i*) The connection of an iron pipe, trap or drain with a stoneware pipe, trap or drain and the connection of a stoneware trap with a stoneware pipe or drain shall be by a joint made with a gasket of hemp or yarn and cement.

"**8. *Slop Sinks and Urinals.***—(1) *Materials, Form of Construction and Flushing.*—A slop sink shall be constructed:

"(*a*) Of glazed earthenware, enamelled fireclay, or other equally suitable material.

"(*b*) Of such shape, and furnished with such flushing rim, water supply, and apparatus as to provide for the effectual flushing and clearing of the slop sink and the trap and waste pipe connected therewith.

"(2) *Materials, Form of Construction and Size of Waste Pipes and Waste Ventilating Pipes.*—A waste pipe from any slop sink, or any urinal, and a waste ventilating pipe shall be constructed of the materials and in the manner prescribed in by-laws Nos. 6 and 17 for soil pipes and soil ventilating pipes, and Table No. III in the schedule to these by-laws.

"Provided always that the internal diameter of the waste pipe of any urinal may be not less than 2 inches in the case of a urinal having not more than two basins, or two stalls or compartments not exceeding 4 feet 6 inches in total width, or $1\frac{1}{2}$ inches in the case of a single urinal basin.

"(3) *Trapping of Waste Pipes.*—Every such waste pipe shall be trapped immediately beneath such slop sink or urinal by a suitable and efficient tubular trap or other equally suitable and efficient trap, and such trap shall:

"(*a*) Be constructed of lead, copper, cast-iron coated or treated as a protection against corrosion in the manner provided for in by-law No. 5 (2) for sewage drains, galvanised wrought-iron, galvanised malleable-iron, glazed earthenware, or other equally suitable material.

"(*b*) Have an outlet with an internal diameter not exceeding the internal diameter of the waste pipe to which it is connected.

"(*c*) Be provided with adequate means for inspection and clearing.

"Provided always that where two or more urinal basins or stalls are fixed in a range the waste pipes may discharge without the interposition of a trap into a semi-circular and accessible open channel of glazed stoneware or other equally suitable material formed or fixed in or on the floor immediately beneath or in front of such basins or stalls, but not extending laterally beyond such range, and discharging into a suitable and efficient trap constructed and fixed in accordance with this by-law, and as prescribed in by-law No. 5 (11) and (12) for sewage drains.

"**9.** ***Ventilation of Traps.***—(1) If the soil pipe or waste pipe of any soil fitment shall be in connection with any other such fitment, or if such soil pipe or waste pipe shall be in connection with the waste pipe of any waste-water fitment, the trap of every such soil fitment or waste-water fitment shall be ventilated in the following manner :

" A trap ventilating pipe shall :

" (*a*) Be connected with the trap or the branch soil pipe or waste pipe :

" (i) At a point not less than 3 nor more than 12 inches from the highest part of the trap.

" (ii) On that side of the water seal which is nearest to the soil pipe or waste pipe.

" (iii) In the direction of the flow.

" (*b*) Be carried into the open air to a point as high as the top of the soil ventilating pipe or waste ventilating pipe and have the open end fitted with a suitable grating or other cover constructed in the manner prescribed in by-law No. 5 (17) (*d*) for gratings to drain ventilating pipes, or into the soil ventilating pipe or waste ventilating pipe at a point above the highest fitment connected with such soil pipe or waste pipe.

" (*c*) Where the vertical distance between the invert of the outlet of the lowest trap connected with the soil pipe or waste pipe and the invert of any horizontal pipe or drain into which such soil pipe or waste pipe discharges or is connected is less than 10 feet, be continued downwards and connected with (i) the soil pipe, waste pipe or drain at a point not less than 9 inches and not more than 2 feet below the invert of the lowest branch soil pipe or waste pipe connection, with adequate means of inspection at the point of connection, or (ii) a manhole in the line of such drain.

" (2) The branch and main trap ventilating pipes respectively shall have in all parts an internal diameter of not less than :

" (*a*) Two inches where connected with a soil pipe, or a waste pipe 3 inches or more in internal diameter.

" (*b*) Two-thirds of the respective internal diameters of the branch and main waste pipes where the internal diameters of such pipes are less than 3 inches, with a minimum internal diameter of $1\frac{1}{4}$ inches.

" (3) Every such trap ventilating pipe shall be constructed of the materials and in the manner prescribed in by-laws Nos. 6 and 7 and Table No. III in the schedule to these by-laws relating to soil pipes and soil ventilating pipes.

" Provided always that if the internal diameter of such pipe is less than $1\frac{1}{2}$ inches such pipe shall be constructed of a suitable non-ferrous material.

" **10.** ***Waste-water Fitments.***—*A waste pipe from a waste-water fitment, a waste ventilating pipe, a trap ventilating pipe, and any trap connected therewith, shall have an internal diameter of not less than* $1\frac{1}{4}$ *inches*

and shall be constructed of the materials and in the manner hereinafter prescribed in paragraphs (1) *or* (2) *of this by-law.*

" (1) *If such waste pipe is constructed so as to dischage over or into a properly trapped gully, such waste pipe and any ventilating pipe and trap connected therewith shall be in conformity with the following requirements:*

" (*a*) *Materials and Fixing.*—Such waste pipe, ventilating pipe and trap shall be :

" (i) Constructed of lead, copper, cast-iron, wrought-iron, glazed stoneware, or other equally suitable material.

" Provided always that if the internal diameter of such pipe or trap is less than $1\frac{1}{2}$ inches such pipe or trap shall be constructed of suitable non-ferrous material.

" (ii) Securely fixed.

" (*b*) *Coating, Thickness, Weight, Joints, Connections, etc.*—If such pipe or trap be constructed :

" (i) Of lead, copper, cast-iron, or wrought-iron, it shall be in conformity with the requirements prescribed in by-laws Nos. 6 (3), (4) and 7 for soil pipes and soil ventilating pipes and Table No. III in the schedule to these by-laws.

" (ii) Of stoneware, it shall be in conformity with the requirements prescribed in by-laws Nos. 5 (3), (5) (*c*) and 7 for stoneware drains.

" Provided always that the joints and connections may be made in an equally suitable and efficient manner.

" (*c*) *Trapping of Waste Pipes.*—Every such waste pipe shall be trapped immediately beneath such fitment by a suitable and efficient tubular trap or other equally suitable and efficient trap, and such trap shall :

" (i) Be constructed in the manner prescribed in by-law No. 8 (3) (*b*) and (*c*) for slop sinks and urinals.

" (ii) Be formed and fixed so as to be capable of maintaining a water seal of at least $1\frac{1}{2}$ inches.

" Provided always :

" (i) That where two or more baths or lavatory basins are fixed in a range the waste pipes may discharge without the interposition of a trap into a semi-circular and accessible open channel of glazed stoneware or other equally suitable material formed or fixed in, on or above the floor immediately beneath such baths or lavatory basins and discharging over or into a suitable and efficient trap constructed and fixed as prescribed in this by-law or as prescribed in by-law No. 5 (12) for sewage drains.

" (ii) That the waste pipe of any sink fixed in an out-building not approached directly from an occupied building need not be trapped if such waste pipe does not exceed 3 feet 6 inches in length and discharges over or into a suitable and efficient trap as prescribed in by-law No. 5 (12) for sewage drains.

"(*d*) *Ventilation of Waste Pipes.*—Where any such waste pipe is connected with two or more such fitments fixed on different storeys of a building it shall be constructed in the manner prescribed in by-law No. 6 (2) (*d*) and (*e*) for soil pipes and soil ventilating pipes.

"(*e*) *Ventilation of Traps.*—In order to preserve the seal of the trap of any such fitment such trap shall be ventilated whenever necessary by a ventilating pipe carried to such a position as to prevent any nuisance or injury or danger to health arising from the emission of foul air from such pipe; and where such pipe is connected to the traps of two or more such fitments fixed on different storeys of a building it shall be carried up as high as the top of the waste ventilating pipe and have the open end fitted with a suitable grating or other cover constructed in the manner prescribed in by-law No. 5 (17) (*d*) for gratings to drain ventilating pipes, or into the waste ventilating pipe at a point above the highest fitment.

"Every such trap ventilating pipe shall be connected with the trap or the branch waste pipe:

"(i) At a point not less than 3 nor more than 12 inches from the highest part of the trap.

"(ii) On that side of the water seal which is nearest to the waste pipe.

"(iii) In the direction of the flow.

"The branch and main trap ventilating pipes respectively shall have in all parts an internal diameter of not less than two-thirds of the respective internal diameters of the branch and main waste pipes.

"Provided always that where the internal diameter of the waste pipe exceeds 3 inches the internal diameter of such ventilating pipe need not be greater than 2 inches.

"(*f*) *Waste Pipes to Discharge in the Open Air over or into a Trapped Gully.*—Every such waste pipe shall be taken through an external wall of the building and shall discharge in the open air over a properly trapped gully or into such gully above the level of the water therein.

"Provided always that where it is impracticable to discharge such pipe in the open air it may discharge within the building into a trap constructed in the manner prescribed in by-law No. 5 (11) and (12) for sewage drains and above the level of the water in such trap.

"Such waste pipe shall not discharge into or connect with any:

"(i) Hopper head.

"(ii) Gutter provided or used for the conveyance of rain water.

"(iii) Pipe constructed or intended to be used for conveying rain water unless such pipe is in its entirety in conformity as regards the manner of construction, material and weight with the requirements in paragraph (1) of this by-law, and unless the rain-water inlet or inlets to such pipe are so situated and con-

structed as to prevent any nuisance or injury or danger to health arising from the emission of foul air from such pipe.

"(2) *If such waste pipe or ventilating pipe is connected directly with any sewage drain, or sewage drain ventilating pipe, or the soil or waste pipe or ventilating pipe of any soil fitment, such waste pipe, ventilating pipe, and any trap connected therewith shall be in conformity with the following requirements:*

"(*a*) *Materials, Form of Construction, and Size.*—Such waste pipe and ventilating pipe shall be constructed of the materials and in the manner prescribed in by-laws Nos. 6 and 7 for soil pipes and soil ventilating pipes and Table No. III in the schedule to these by-laws.

"Provided always that the internal diameter of such waste pipe or ventilating pipe may be less than 3 inches, but shall be not less than $1\frac{1}{4}$ inches.

"(*b*) *Trapping of Waste Pipes.*—Every such waste pipe shall be trapped immediately beneath such fitment by a suitable and efficient tubular trap or other equally suitable and efficient trap, and such trap shall:

"(i) Be constructed in the manner prescribed in by-laws Nos. 5 (12) for sewage drains, and 8 (3) (*a*), (*b*) and (*c*) for slop sinks and urinals.

"(ii) Be ventilated in the manner prescribed in by-law No. 9 for the ventilation of traps of soil fitments.

"Provided always that if the internal diameter of such pipe or trap is less than $1\frac{1}{2}$ inches such pipe or trap shall be constructed of suitable non-ferrous material.

"**11.** ***Marking of Pipes, Traps, etc.***—No pipe, trap, apparatus or fitment bearing or marked with the letters or words 'L.C.C.' or 'London County Council' or any reference thereto shall be used in connection with any drainage work unless such pipe, trap, apparatus or fitment is in conformity with the requirements of these by-laws.

"**12.** ***Maintenance in State of Repair, etc.***—The owner of any house or building shall at all times keep and maintain in a proper state of repair and in proper working order all drainage work in or in connection with such house or building, and he shall at all times keep and maintain in conformity with these by-laws all such drainage work constructed in accordance with these by-laws.

"**13.** ***Alteration, Reconstruction and Repair.***—No alteration, partial or entire reconstruction, or repair of any drainage work constructed in accordance with these by-laws shall be made so that by reason of such alteration, partial or entire reconstruction or repair any such drainage work will not be in conformity with these by-laws.

"The alteration, partial or entire reconstruction, or repair of any drainage work shall, so far as practicable, be carried out so as to comply

with these by-laws in respect of such alteration, partial or entire reconstruction or repair.

"**14.** ***Plans and Notices of Drainage Work.***—(1) (*a*) *Deposit of Plans, etc., of Drainage Work.*—Every person about to construct, reconstruct, or alter any drainage work, shall deposit or cause to be deposited in duplicate with the sanitary authority at their office such plans, sections and block plan, clearly and indelibly made on cloth or linen, and such detailed description and particulars of the proposed construction, reconstruction or alteration as may be necessary for the purpose of enabling such authority to ascertain whether such construction, reconstruction or alteration will be in accordance with the statutory provisions relative thereto and with these by-laws.

"In the case of any addition to or alteration of any drainage work so much of the existing work shall also be shown on such plans and sections as will enable the sanitary authority to see the relative positions of the new and old work, and if plans and sections of the existing work have previously been deposited the builder or person about to carry out the new work shall furnish or cause to be furnished to the sanitary authority the date of the previous deposit.

"The plans, sections, detailed description and particulars hereinbefore mentioned shall be signed by or on behalf of such person and deposited seven days at least before such construction, reconstruction or alteration is commenced, and in the case where such construction is in connection with a building to be erected seven days at least before commencing the erection of the building.

"(*b*) *Plans, Sections and Particulars.*—Such plans and sections shall be drawn to a scale (except in the case of block plans) of not less than 1 inch to every 16 feet, and shall show:

"(i) The position of every soil fitment, waste-water fitment, apparatus and trap in connection therewith.

"(ii) The fall of every drain.

"(iii) The position and size of every drain, means of access, trap, gully, soil pipe, waste pipe, ventilating pipe and rain-water pipe.

"(iv) The height and position of every chimney belonging to and the position of every window or other opening into the building in connection with which such work is to be executed within a distance of 20 feet from the open end of a soil pipe or ventilating pipe.

"(v) The levels of the lowest floor of the building in connection with which such work is to be executed and the adjoining street.

"(vi) The level of any yard, area, ground or open space in connection with such building.

"(vii) The scale to which such plans are drawn.

"(*c*) *Block Plan.*—Such block plan shall be drawn to a scale of not less than 1 inch to every 88 feet and shall show:

"(i) The premises upon which such work is to be carried out.

"(ii) The position of the buildings on such premises, and so much of the properties adjoining thereto as may be affected by such work.

"(iii) The names of the streets or thoroughfares immediately adjoining such premises, and the number or designation of such premises.

"(iv) The lines, size, depth and inclination of the proposed drains, and, so far as can be ascertained without opening the ground, the lines, size, depth and inclination of the existing drains, and the arrangements for the ventilation of the drains—the existing drains and the proposed drains to be distinctively indicated by different colours.

"(v) The points of the compass.

"Provided, nevertheless, that it shall not be necessary to deposit a block plan in any case where the plans, sections, and particulars deposited in accordance with paragraph (*b*) of this by-law clearly show the particulars required to be shown on a block plan.

"(*d*) *Detailed Description.*—Such detailed description shall sufficiently describe the intended mode of constructing such soil fitment, waste-water fitment, apparatus, trap, drain, means of access, gully or pipe.

"(2) *Notice of Drainage Work.*—Such person shall also serve or cause to be served upon the sanitary authority at their office at least twenty-four hours' notice in writing of the day and time at which any work of construction, partial or entire reconstruction, or alteration is to be commenced.

"(3) *Urgent Cases.*—In any case in which any partial or entire reconstruction or alteration of drainage work must be carried out at once, the builder may, in lieu of depositing the plans, sections, detailed description and particulars and serving the notice referred to in this by-law before commencing such work, forthwith send to the sanitary authority a notice in writing of such work.

"Provided always that he shall within fifteen days of the commencement of such work make or cause to be made the deposits required by this by-law.

"(4) *Exemption.*—Nothing in this by-law shall require the deposit of any plan or section in the case of any repair which does not involve the alteration or the entire reconstruction of any drainage work.

"**15.** ***Penalty.***—Every builder who shall offend against any of the foregoing by-laws and every owner who shall offend against by-law No. 12, and every person who shall offend against by-law No. 14, shall be liable for every such offence to a penalty of two pounds, and in the case of a continuing offence to a further penalty of twenty shillings for each day after written notice of the offence is given in accordance with Section 202 of the Metropolis Management Act, 1855.

"Provided always that no proceedings shall be taken against an owner for an offence against by-law No. 12, unless and until written notice has

been served upon him by the sanitary authority requiring him within a period as is specified in the notice to comply with the by-law and he has failed to comply with the by-law within the time so specified.

"**16.** ***By-laws Not to Apply to City.***—These by-laws shall not extend to the City of London.

"**17.** ***Repeal.***—From and after the date of the approval of these by-laws the by-laws made by the London County Council under section 202 of the Metropolis Management Act, 1855, and the Metropolis Management Acts Amendment (Byelaws) Act, 1899, and approved by the Minister of Health on 4th March, 1930, shall be repealed, except as regards any drainage work commenced before the date of the confirmation of these by-laws or any drainage work not so commenced, but of which plans shall either have been approved by the sanitary authority before such date, or have been sent to the sanitary authority one month at least before such date, and shall not have been disapproved by the sanitary authority. Provided that this exception shall not be deemed to prohibit any such work from being executed in accordance with, or so as not to contravene, the foregoing by-laws.

"SCHEDULE[1]

"TABLE NO. I—CAST-IRON DRAIN PIPES

Internal diameter.	Internal depth of socket not less than	Caulking space not less than	Thickness of metal for pipes, traps and fittings not less than	Weight of pipes (including socket and beaded spigot or flanges) not less than
Inches.	Inches.	Inches	Inches.	
2	$2\frac{3}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	42 lb. per 6-foot length
3	3	$\frac{5}{16}$	$\frac{5}{16}$	98 lb. per 9-foot length
4	3	$\frac{5}{16}$	$\frac{3}{8}$	157 ,, ,,
5	3	$\frac{3}{8}$	$\frac{3}{8}$	186 ,, ,,
6	$3\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{8}$	225 ,, ,,
7	4	$\frac{3}{8}$	$\frac{7}{16}$	316 ,, ,,
8	4	$\frac{3}{8}$	$\frac{15}{32}$	370 ,, ,,
9	4	$\frac{3}{8}$	$\frac{1}{2}$	441 ,, ,,

"TABLE NO. II—STONEWARE DRAIN PIPES

Internal diameter.	Internal depth of socket not less than	Jointing space not less than	Thickness of pipes, traps and fittings not less than
Inches.	Inches.	Inches.	Inches.
3	2	$\frac{5}{16}$	$\frac{7}{16}$
4	2	$\frac{3}{8}$	$\frac{1}{2}$
5	$2\frac{1}{4}$	$\frac{7}{16}$	$\frac{9}{16}$
6	$2\frac{1}{4}$	$\frac{7}{16}$	$\frac{5}{8}$
7	$2\frac{1}{4}$	$\frac{7}{16}$	$\frac{11}{16}$
8	$2\frac{1}{2}$	$\frac{1}{2}$	$\frac{11}{16}$
9	$2\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{4}$

"[1] It should be noted that the first column in each of the three tables in the schedule is an index to the particulars given in the table and does not fix the internal diameter of any pipe.

"The weights of pipes given in the tables are minimum weights and will not be suitable in all circumstances. In determining the weight to be used, regard must be had to (*a*) the strength of pipe needed to resist the internal working 'head' or pressure, and (*b*) the possibility of such pipe being used for the conveyance of hot liquids."

"TABLE NO. III—SOIL PIPES, WASTE PIPES AND VENTILATING PIPES

Internal diameter.	Lead.	Copper.	Cast-iron.				Wrought-iron.	
	Weight per yard *not less than*	Weight per yard *not less than*	Internal depth of socket not less than	Caulking space not less than	Thickness of metal for pipes, traps and fittings not less than	Weight of pipes per 6-foot length (including socket and beaded spigot or flanges) not less than	Thickness of metal for wrought-iron pipes and wrought-iron, cast-iron or malleable-iron traps and fittings not less than	Weight of pipes per yard (not including sockets or flanges) not less than
Inches.	lb.	lb.	Inches.	Inches.	Inches.	lb.	Inches.	lb.
$1\frac{1}{4}$	6·25	2·25	—	—	—	—	0·176 [2] [3]	7·94 [3]
$1\frac{1}{2}$	7·5	2·7	$2\frac{1}{4}$	$\frac{1}{4}$	$\frac{3}{16}$	22	0·192 [2]	9·82
2	10·0	4·17	$2\frac{1}{2}$	$\frac{1}{4}$	$\frac{3}{16}$	24	0·192 [2]	12·51
$2\frac{1}{2}$	12·5	5·19	$2\frac{3}{4}$	$\frac{1}{4}$	$\frac{3}{16}$	30	0·212 [2]	17·64
3	15·0	7·11	$2\frac{3}{4}$	$\frac{1}{4}$	$\frac{3}{16}$	35	0·212 [2]	20·82
$3\frac{1}{2}$	19·5	9·33	3	$\frac{1}{4}$	$\frac{3}{16}$	41	0·212 [2]	23·97
4	22·5	11·85	3	$\frac{1}{4}$	$\frac{3}{16}$	46	0·212	27·13
$4\frac{1}{2}$	29·0	13·29	$3\frac{1}{4}$	$\frac{5}{16}$	$\frac{1}{4}$	66	0·212	30·3
5	41·0	14·76	$3\frac{1}{4}$	$\frac{5}{16}$	$\frac{1}{4}$	78	0·212	33·45
6	57·0	17·64	$3\frac{1}{2}$	$\frac{5}{16}$	$\frac{1}{4}$	92	0·212	39·78

"The foregoing by-laws were made by the Council on the sixth day of March, 1934, and confirmed by the Council on the fourteenth day of March, 1934.

"The seal of the Council was hereunto affixed on the second day of July, 1934.

L.S.

"G. H. GATER,
"*Clerk of the London County Council.*

"The County Hall, S.E.1.

"*The foregoing by-laws except so much of the table numbered* 3 (*three*) *in the schedule as requires a greater thickness of metal than is specified in the second column in this certificate for malleable-iron traps and fittings of an internal diameter not less than is specified in the first column opposite to each thickness:*

Inches.	Inches.
$1\frac{1}{4}$	·13
$1\frac{1}{2}$	·14
2	·16
$2\frac{1}{2}$	·17
3	·19
$3\frac{1}{2}$	·19

are hereby allowed by the Minister of Health this twenty-eighth day of July 1934.

L.S.

"E. H. RHODES,
"*Assistant Secretary, Ministry of Health.*"

"[2] See terms of allowance of the by-laws by the Minister of Health."

"[3] In virtue of by-laws 6, 8, 9 and 10, the practical application of this size of pipe in wrought-iron is limited to partial reconstruction or repair of existing pipes of less than $1\frac{1}{2}$ inches internal diameter."

SEWERS

Definition and Rights.—The distinction between a *drain and a sewer* is generally understood to lie in the fact that *a drain* is taken as meaning a conduit for sewage within the boundaries of a site, whilst *a sewer* is a conduit outside the boundary. Though the legal definition has been productive of considerable uncertainty and consequent actions at law, the distinction may be taken as largely a matter of ownership.

In the Public Health Act, *a Drain* is defined as :

" Any drain of and used for the drainage of one building only, or premises within the same curtilage, made merely for the purpose of communicating therefrom with a cesspool or other like receptacle for drainage, or with a sewer into which the drainage of two or more buildings or premises occupied by different persons is conveyed."

Whilst the term *Sewer* is defined as including :

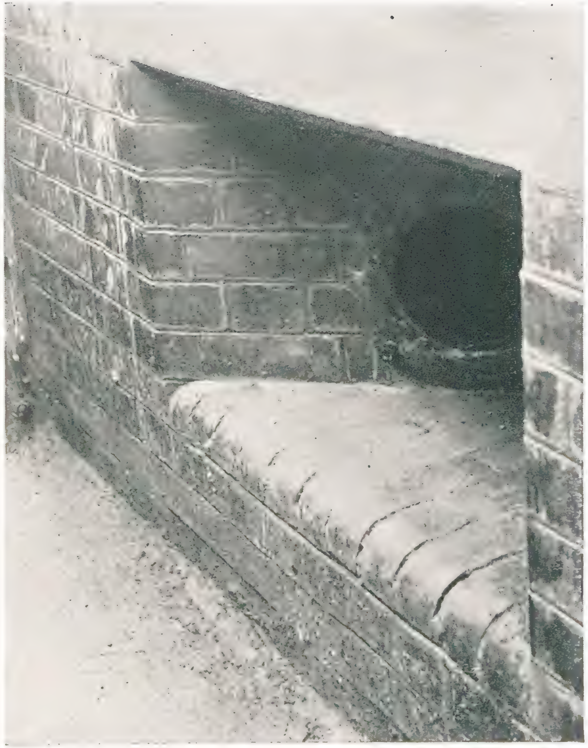
" Sewers and drains of every description, except drains to which the word ' drain,' interpreted as aforesaid, applies, and except drains vested in or under the control of any authority having the management of roads, and not being a Local Authority under this Act.

" Sewers are regarded as being the property of the local authority except when constructed by an individual or a company for their own profit, or constructed by right of any local or private Act of Parliament, or under the authority of any Commissioners of Sewers appointed by the Crown."

So that the conduits of sewage along the roads of an estate may be under private ownership, but this private ownership is subject to compulsory purchase by the Local Authority ; the Act stating that :

" Any Local Authority may purchase or otherwise acquire from any person, any sewer, or right of making, or of using, or other right in or respecting a sewer (with or without any builder's work, materials, or other things belonging thereto) within their district, and any person may sell or grant to any such authority any such sewer right or property belonging to him ; and any purchase money by such authority in pursuance of this section shall be subject to the same trusts (if any) as the sewer right or property sold was subject to. But any person who, previously to the purchase of a sewer by such authority has acquired a right to use such sewer shall be entitled to use the same, or any sewer substituted in lieu thereof, to the same extent as he would or might have done if the purchase had not been made."

Concerning the Alteration of Sewers the Act states that : " Any Local Authority may from time to time enlarge, lessen, alter the course, cover in, or otherwise improve any sewer belonging to them, and may discontinue, close up, or destroy any such sewer that has, in their opinion, become unnecessary, on condition of providing a sewer as effectual for the use of any person who may be deprived in pursuance of this section of the lawful use of any sewer ; provided that the discontinuance, closing



PIPE OUTLET INTO BRICK SEWER.

LAYING SALT-GLAZED SEWER PIPES.

(Courtesy of Doulton & Co. Ltd.)

LOWERING 24-INCH SALT-GLAZED SEWER PIPES.
(Courtesy of Doulton & Co. Ltd.)

up, or destruction of any sewer, shall be so done as not to create a nuisance."

Construction.—Sewers may be formed of large pipes where the cubic capacity required is not so great as to render their use impracticable. Earthenware pipes are cheaper for small diameters and brickwork is not suitable for these, in that the joints are so wide on the outside or extrados in a small-diameter pipe. For any sewer pipe under 18 inches an earthenware pipe will be found more economical.

Sewers not over 3 *feet* in diameter do not require more than one ring, *i.e.* 4½ inches of brickwork in their construction.

Another form of sewer, though not one in general use, consists of a semicircular inverted arch, having vertical sides covered with flat stone slabs. This type has the advantage of affording ready access to the sewer in the event of stoppage, by the removal of one or more of the flat stone coverings.

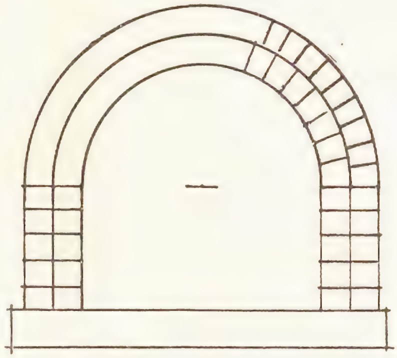


Fig. 148.—Arched sewer.

The most usual form of sewer constructed in modern work is *egg-shaped* in section. The advantage gained by the use of this section is that where the flow of sewage is intermittent, during the periods when the amount of fluid is small, solids are not so readily deposited on the sides of the sewer as when the circular form is used. The increased depth gained by the decreased diameter or width of flow increases the rate of flow during the times when the quantity of liquid is small. Whereas during the times when the quantity is greater the level of the liquid rises into the circular portion of the egg shape, and the rate of the flow is consequently retarded.

The excavation for a sewer trench is similar to that already described for drains, with the exception that the bottom of the trench instead of being dug square is formed curved. The concrete also should be laid in on the curve, as no additional payment is made for concrete of greater depth than that called for in the specification and necessitated only by unnecessary excavation.

Timbering to sewer trenches is similar to that described for drains, unless it be decided, on account of expense and depth, to tunnel rather than to excavate.

In *tunnelling* for sewer trenches, shafts are sunk, one, at least, at every bend in the direction of the line of sewer and not less than 80 yards apart in any event.

Where the depth of the sewer is required to be more than 15 feet it will generally be found more economical to tunnel rather than to excavate. But the decision as to whether tunnelling or excavation should be undertaken will depend to a large extent upon whether the

sewer is to be run across open country or along the crowded thoroughfares of a town where the excavated material will present an obstruction and also the weight of the buildings on either hand will be likely to cause danger from subsidence. In such conditions as the latter it may be advisable to tunnel for a depth of 12 feet only.

Shafts are excavated as already described, and the timbering becomes a matter in which additional care in construction is required. In loose soil an iron or timber kerb is sometimes constructed, on top of which brickwork is constructed, the kerb being sunk by means of the soil being excavated on the inside, the brickwork being built up as the excavation proceeds. The shaft will then form a permanent manhole to the sewer. The levels of the trench in tunnelling can be checked only by the erection of sight rails in the shafts.

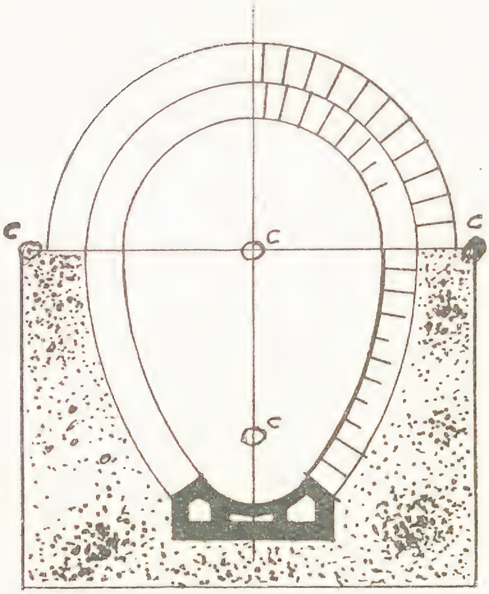


Fig. 149.—Egg-shaped sewer.

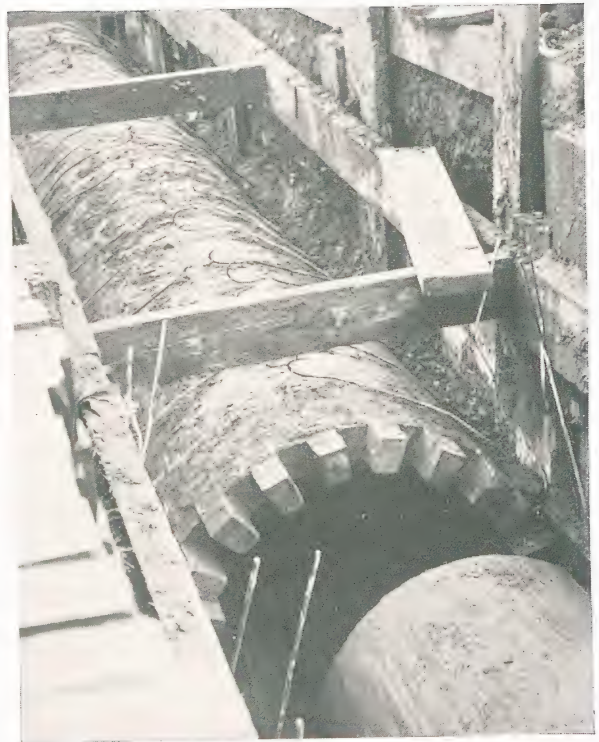
The operation of tunnelling is carried out as follows:

To give the centre line of the sewer and the exact depth of the invert required to give the proper gradient, plumb lines are suspended from the centre mark on the sight rails and directly under these at the exact depth, measured down the plumb lines, a stone flag set in concrete is laid. This gives the level of the invert of the sewer. The level to which the excavation of the tunnel is required to be carried out may be then measured from these slabs as *datum.*

In soft ground or loose soil, the timbering of the tunnel becomes a matter of extreme importance, not only on account of economy, but also of the risk to life from falling in.

After a preliminary excavation has been made horizontally from the bottom of the shaft to such distance as will occasion no danger of collapse (this distance will naturally depend on the nature of the soil), a horizontal excavation is commenced. The height of this horizontal excavation must be sufficient to provide room for a man to work in. When about a 2-foot depth has been excavated, boards having chisel-end metal shoes are driven in horizontally close against the top of the excavation. A support is then shored up under the ends of these boards at the beginning of the excavation and the excavation is then continued another 2 feet. More boards are next driven in below the first series, their points being given a slightly upwards direction, until a point near the ends of the first series

CONNECTION OF SEWER PIPE TO BRICK MANHOLE.



BRICK SEWER WITH REINFORCEMENT IN POSITION FOR CONCRETING.

(Courtesy of Doulton & Co. Ltd.)

24-INCH WATER SEWER SUPERIMPOSED ON EXISTING FOUL SEWER.

(Courtesy of Doulton & Co. Ltd.)

is reached, when another cross support is shored up under them. So the work is proceeded with. Temporary cross supports and shores may be required as the excavation nears the points (driven in) of each series; but these may be removed when the shoring to the new series is in position.

Timbering to Tunnels in Soft Ground will require close-boarded sheeting, not only overhead, but also at the sides; and the tunnel in section should be formed narrower at the top than at the bottom. To hold the sheeting in position, vertical waling is required. This supports a head, over which is the roof sheeting; and the tops of the waling pieces are strained apart by horizontal struts.

These timbers must be left in position in soft ground after the sewer is built, and the spaces over and at the side of the sewer must be packed with either clay or a weak cement concrete. This filling-in or packing must be done as the work of building the sewer proceeds, and requires constant supervision against scamping. Supervision should include the removal of two or three bricks in the covered-up part as a test of the thickness of the sewer walling throughout its length.

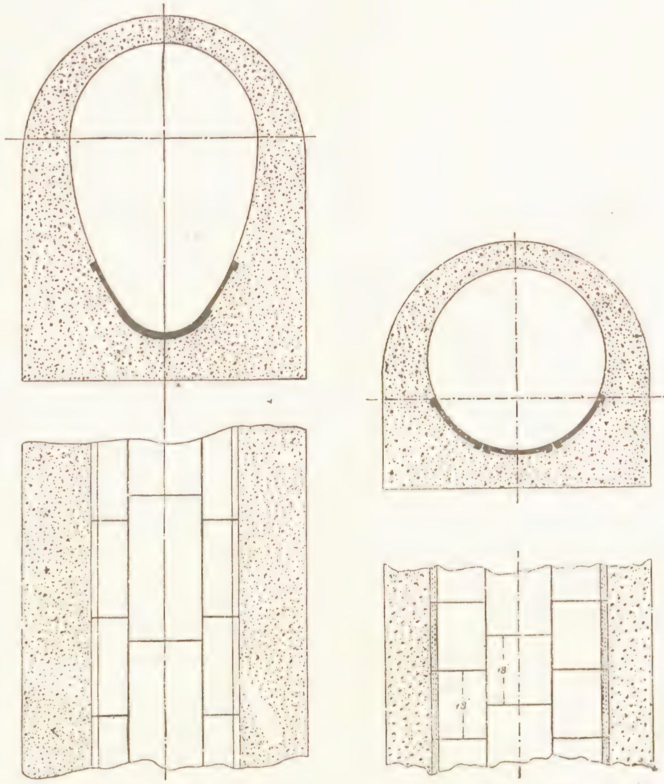


Fig. 150.—Concrete sewer with glazed stoneware invert tiles.

Sewers in quicksand or bog should be built in concrete and supported on the heads of piles driven into a solid stratum, if such is to be found within reasonable depth. Over the heads of the piles, steel girders or wood beams are laid along the trench supporting a raft on which the concrete is laid. The sewer pipe is then constructed on the concrete layer, and the concrete is packed round as the work proceeds. Here, again, constant supervision is advisable.

The bricks used in the construction of sewers must be hard, impervious engineering bricks and set in cement mortar. The inverts are frequently constructed of glazed terra-cotta or fireclay blocks, which are termed

invert blocks. This invert block is set in concrete on a flat base, and its upper surface is formed in a curve which is part of the circle of which the bottom of the egg-shape is an arc.

To draw the Section of the egg-shape sewer—first describe a circle of which the invert forms an arc. The diameter of this circle is half the

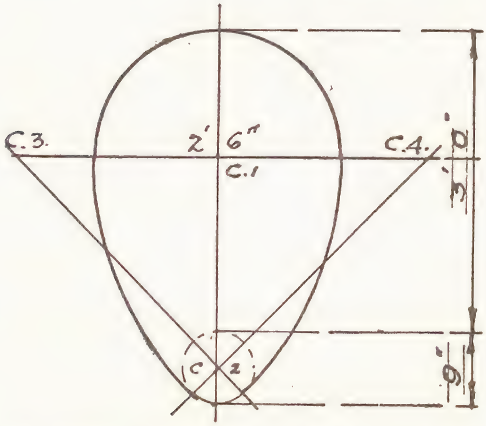


Fig. 151.—Method of drawing the section of egg-shaped sewer.

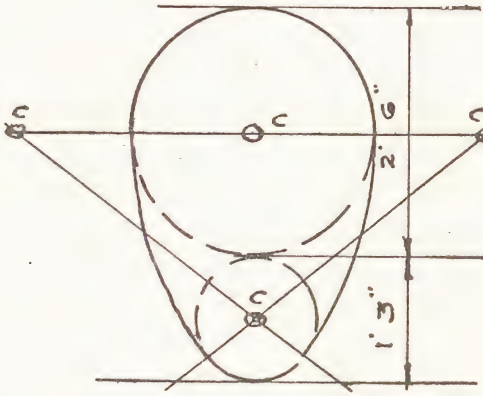
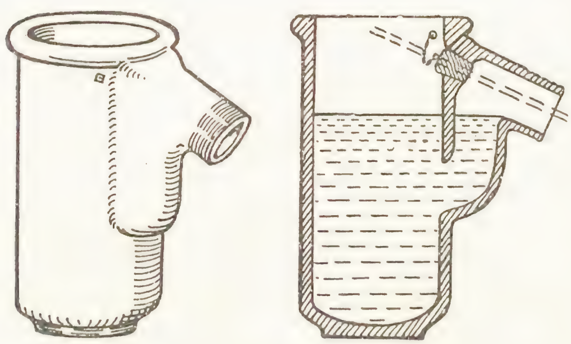


Fig. 152.—Alternative method of drawing section of egg-shaped sewer.

radius of the arch; therefore, to describe the arch, draw a circle touching the first-drawn small circle having a radius of a length twice the diameter of the smaller circle. The centre of the circle of which the sides are an arc is formed by drawing a horizontal line through the centre of the upper circle and marking the points at which a distance of $2\frac{2}{3}$ the radius of the larger circle cuts it. These points are the centre of the circles of which the sides are arcs, so that the section of the sewer may be completed with the compasses.



View. Section.

Fig. 153.—Road storm-water gully. (Leeds Fireclay Co. Ltd.)

The Dimensions of an Egg-shaped Sewer.—For use in drawing, the following dimensions will be found helpful, where R = the radius of the arc, or upper circle: height = 3R; width = 2 R; radius of invert = 0·5R; radius of sides = $2\frac{2}{3}$R.

Centering for Sewers.—The side arches from the invert to the springing of the top arch are built to fit templates, and from these springings the top arch is formed over centerings in short lengths of about 3 feet. This centre must be strutted up and wedged, so that the wedges may be

withdrawn to enable the centre to be removed along the sewer as the work proceeds. The ribs and laggings should be of light material, and the laggings butt jointed.

Ventilation.—There must be alternate inlet and outlet vents to a sewer, and the outlets must be carried up to a height away from all buildings.

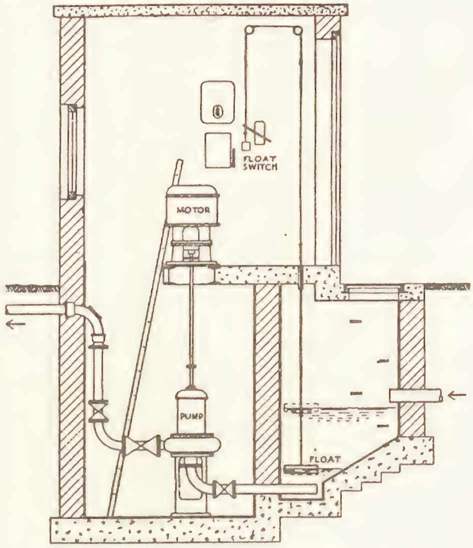


Fig. 154.—Sewage lifting plant.

Manholes.—To provide access to the sewer, manholes must be constructed at convenient points at intervals of about 50 yards and at all junctions and bends. These must be built in gault bricks, 9 inches thick, with two courses of footings on 12 inches of concrete. The top is to be provided with a cast-iron cover and frame, 22-inch diameter cover, and frame with square base and dirt pan.

In two alternate corners of the manhole there must be fixed at about

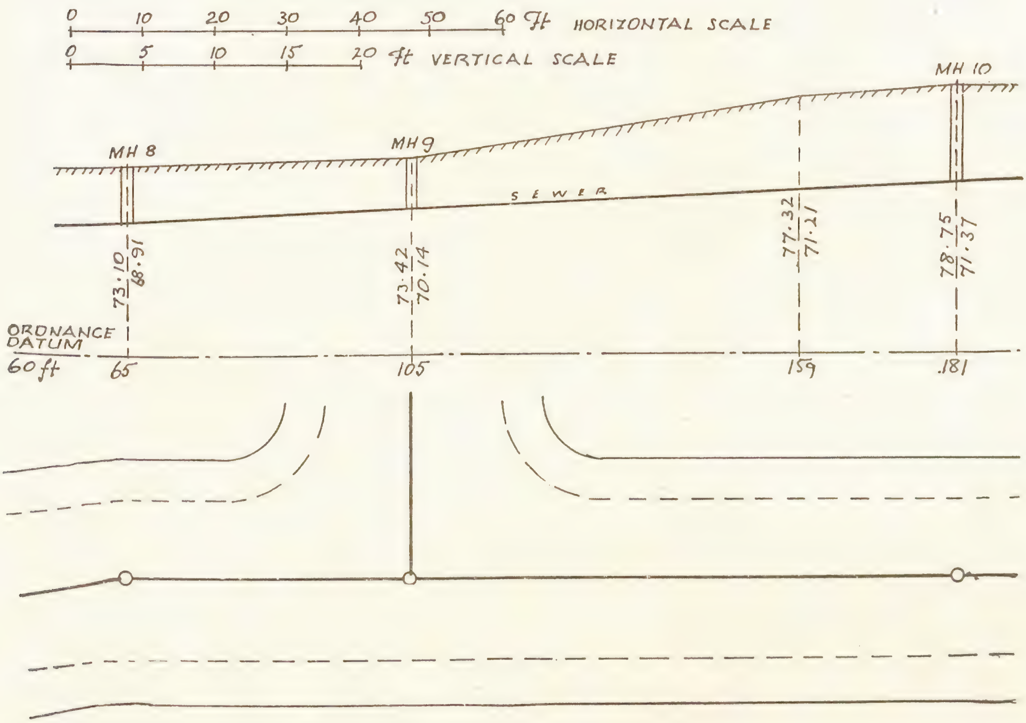


Fig. 155.—Section and plan for sewering.

12-inch distance wrought foot irons, $1\frac{1}{2}$ inches $\times$ $\frac{1}{2}$ inch metal $\times$ 15 inches long ; and these and all metal must be painted two coats before fixing in torbay paint and two coats after fixing in ordinary paint.

Cleaning Out.—At completion all rubbish and cement droppings must be cleaned out of the sewer and manholes. All irregularities in jointing must be cut away or taken up and relaid.

Road Gully.—This is a large deep gully for collecting water from road gutters. The deep bottom below the trap outlet (see Fig. 153) enables grit and mud to be collected and periodically emptied.

Sewage Lifting Plant.—Where the drain outlet is below the level of the sewer, a sewage lifting plant can be installed. An example is illustrated in Fig. 154. It consists of a pump driven by an electric motor and operated automatically by a float switch.

Sewer Sections.—Plans and sections have to be prepared for sewer layouts. The vertical scale is usually greater than the horizontal scale, as shown in Fig. 155. This exaggerates the fall of the surface and the sewer, but is convenient for scaling depths and levels off the drawing.

CHAPTER 11

SCAFFOLDING AND HOISTING

A GOOD definition of a scaffolding is the following : a temporary erection of timber or other material used to support workmen, structural materials, machinery, and appliances, during the erection, alteration, repair, or demolition of buildings ; also used where and when required in connection with the hoisting, lowering, and distribution of structural materials and appliances.

KNOTS USED IN SCAFFOLDING

The knots and lashings used in constructing a scaffolding are shown in Fig. 156. Nos. 24 and 25 of this illustration show the method of lashing the ledgers to the standards. A start is made with two half-hitches as shown in No. 23. The rope is then twisted round the short end of the half-hitch, when the ledger is held in position above the half-hitches, as shown in No. 24. The twisted ropes are then drawn up in front of the ledger to the left of the standard, and taken round the back of the standard level with the top of the ledger and then brought to the front and over the ledger to the right of the standard, then under the ledger and behind the standard.

This procedure is continued until the long end of the rope is reached, when it is twisted under one of the cross strands on one of the ledgers.

For lengthening scaffold poles either for use as standards, ledgers, or bracings, the knot used is shown in Nos. 21 and 22. This is known as the *Marrying or Splicing Band Tie,* and is formed by starting, as shown in No. 21, by giving the rope three turns round the two poles to be joined together, the end of the rope being tucked in under the three turns. The other end is then pushed between the two timbers twice and pulled tight round the turns already made. The loose end is then jammed in under the turns and wedges are then driven in between the turns of the rope and the timbers to tighten the whole.

The scaffolder works with an axe fitted with a hammer head, which he uses as a lever for tightening the lashings, as well as for hammering in the wedges and beating the turns of the rope into position.

The other knots and lashings, used either in connection with scaffolding, or with tackle on buildings, are shown in the remaining diagrams.

No. 1 of the same illustration shows the method of preventing the end

of the rope from fraying, or from passing through the sheaves of a block, and this is known as the *Overhand or Thumb Knot.*

No. 2 is a more elaborate form of knot used for the same purposes and to make a larger knot.

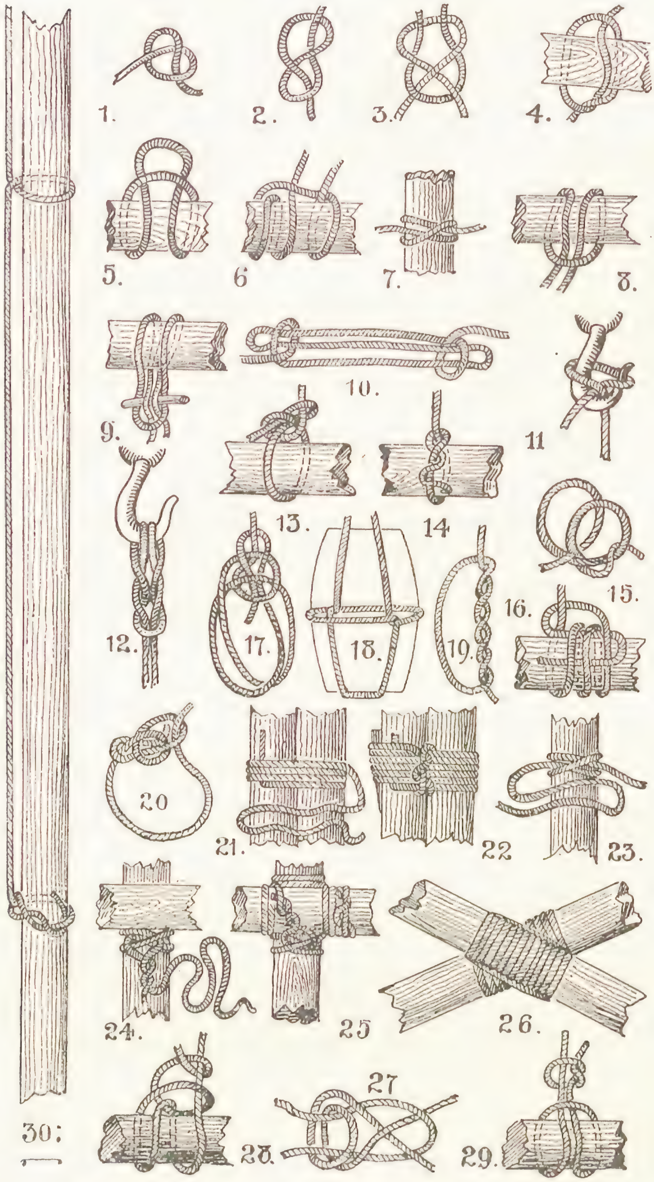


Fig. 156.—Knots used in scaffolding and hoisting.

For joining rope together or securing a rope through an eye splice the *Bend or Weaver's Knot,* as shown in No. 3.

Where a pole is used as a lever, and it is desired to prevent the rope attached to it from slipping, the *Wolding Stick Hitch* is used, as shown in No. 4.

For hanging materials on to a hook of lifting tackle, the *Bale Sling* is used—No. 5.

For lifting material a *Rolling Hitch* is used, as shown in No. 6.

Two Half-hitches are used for tying ledgers to standards. These are shown in No. 7.

For use where ends of rope are not available—No. 8.

To attach a rope to a timber where the end of pole is not available, use the *Loop Knot,* as shown in No. 9.

Where it is required to shorten a rope without cutting, a *Sheep Shank*—No. 10—is the method employed.

For securing a rope on to a hook so that it will not slip, the *Midshipman's Hitch,* shown in No. 11, should be used.

No. 12 shows the *Catspaw,* which is a loop for the same purpose as the last, but where considerable strength is required.

LEDGERS, STANDARD AND ROPE LASHING.

BRICKLAYERS' SCAFFOLD—FIRST STAGE.
(Both photos by Edgar Lucas.)

No. 13 shows the *Capstan Knot*, or *Bowline* which, when tightened round the rope, will not slip.

No. 14 shows the *Timber Hitch*, which is used for raising scaffold poles.

The Artificer's Knot, shown in No. 15, consists of a half-hitch and an overhand.

No. 16 is the *Topsail Halliard Bend*, used as a timber hitch.

Nos. 17 and 18 show the *Butt or Barrel Sling* for use horizontally and vertically.

No. 19 is the *Double Overhand Knot*.

No. 20 is the *Running Bowline*.

No. 26 is the method of lashing the braces to the standards, or braces where they cross one another, and is also a form of lashing used for attaching shear legs together at the top, so that they will not spread outwards beyond a certain distance.

No. 27, the *Double Bend*. Where it is required to attach a small rope to a larger one, this knot is used to prevent it slipping.

No. 28 shows the *Fisherman's Knot*.

No. 29, *Lark's Head*, which forms a running knot, and in No. 30 is shown the method of attaching a rope to scaffold poles for the purpose of raising them to the vertical position. This consists of a timber hitch at the bottom and a half-hitch.

BRICKLAYERS' SCAFFOLDING

The ordinary type of scaffolding used on the exterior of buildings for their erection and repair is known as the *Bricklayers' Scaffolding*. This consists of upright poles either buried in the ground or supported in barrels filled with earth, or sole pieces consisting of planks laid on the ground, the feet of the poles being framed round with 4 × 4-inch boxing to prevent slide movement. The poles known as *Standards* are fir poles in lengths varying from 10 feet to 30 feet, and of a diameter of about 5 inches at the bottom end. They are placed at a distance of about 4 feet 6 inches from the face of the building, and at distances from 8 feet to 12 feet apart. Where they enter the ground they should be sunk for a distance of 2 feet.

Across these standards are lashed up horizontally other poles ; these are spaced at from 4 feet to 5 feet apart measured vertically.

Across these, spanning the distance between the scaffolding and the building, are laid short lengths of birch 3 inches square. The distance apart of these is from 4 feet to 5 feet, except where junctions are made in the boarding which, as is described below, forms the platform of the scaffolding. In these positions they are laid double. These are known as *Putlogs*.

Over the putlogs are laid *Scaffold Boards*, generally from 8 feet to

12 feet in length, to form a platform for the workmen and materials. The ends of these boards are bound with hoop-iron, and they are laid

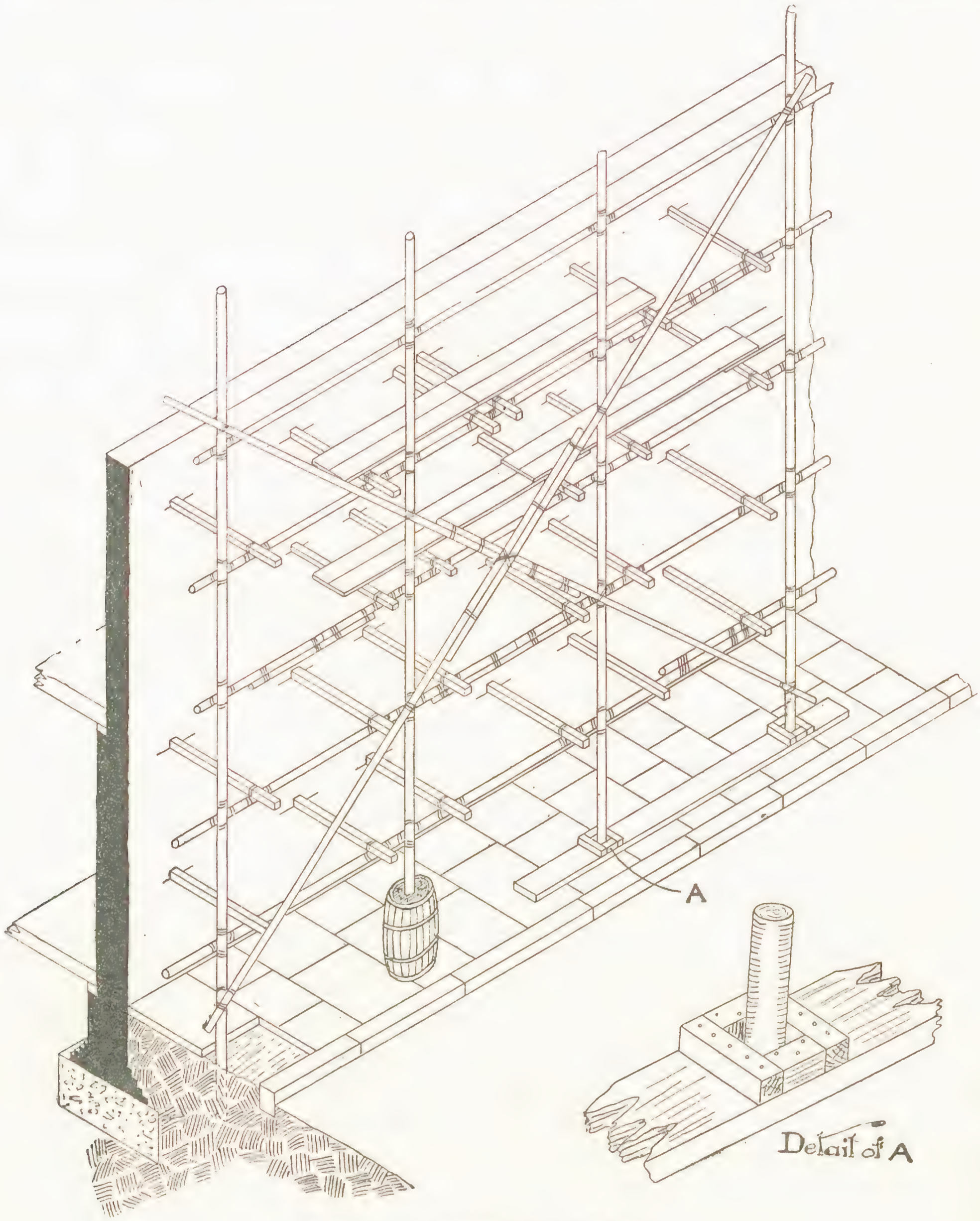


Fig. 157.—Bricklayers' scaffolding.

either with the ends overlapping or with two putlogs close together and the ends of the boards butted.

Guard Boards are scaffold boards placed on edge at the outside of the platform, and against the scaffold pole, to prevent materials dropping.

A handrail is lashed to the poles at a height of 3 feet 6 inches above the platform, and is known as a *Guard Rail.*

Where the putlogs enter the wall, spaces will be left in the brickwork. These will require to be filled with bricks after the building is finished, and before the scaffolding is taken down.

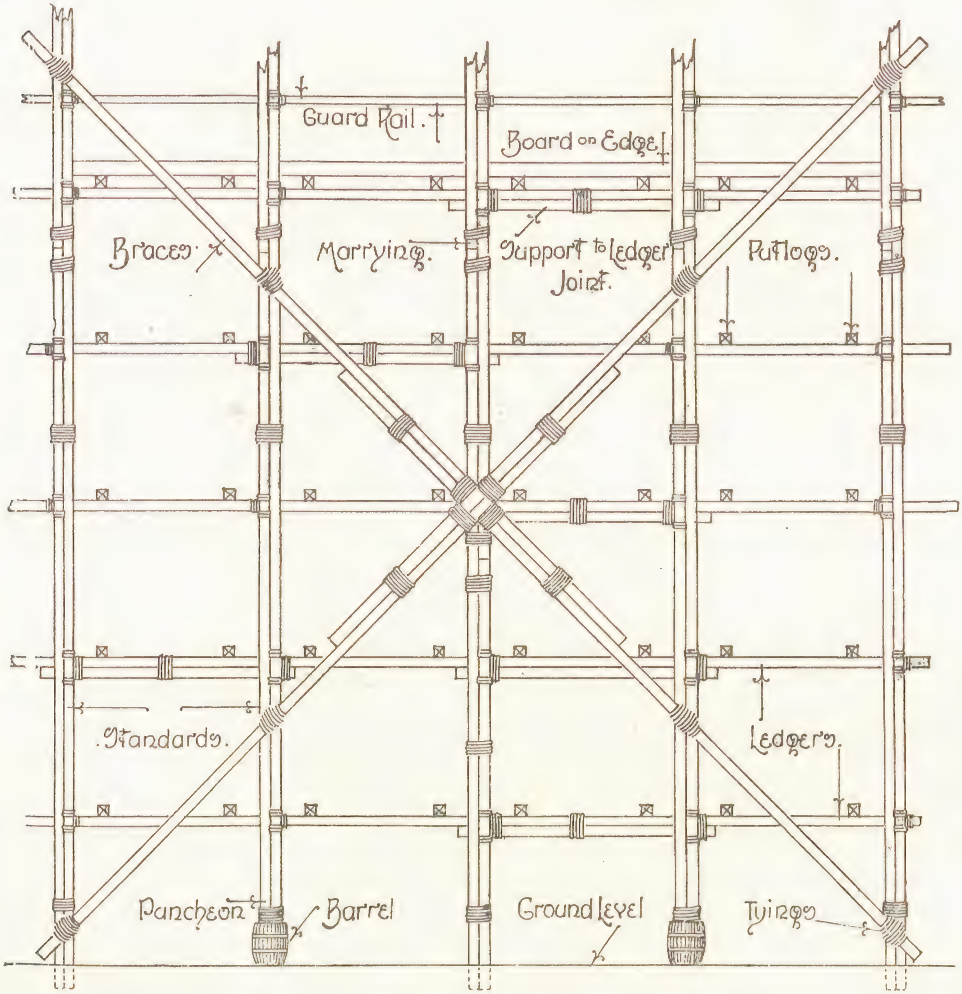


Fig. 158.—Bricklayers' scaffolding—Details.

To stiffen the scaffolding, *Cross Braces*, running from the base of a standard to just above the highest guard rail, are lashed to the standards. Where poles are required to be lengthened for use as standards, ledgers, or braces, they are lengthened by being overlapped and lashed together, as shown in diagrams 21 and 22 of Fig. 156.

THE MASONS' SCAFFOLDING

For buildings constructed of stonework, and other heavier materials than brickwork, a double scaffolding is required. This consists of an inner and outer row of standards and ledgers, the inner row being placed about 6 inches distant from the wall. The uprights are placed from 4 feet to 5 feet apart. The inner and outer frameworks of scaffolding are connected together by cross ledgers lashed to the longitudinal ledgers, transverse braces also being fixed between the two frames where required.

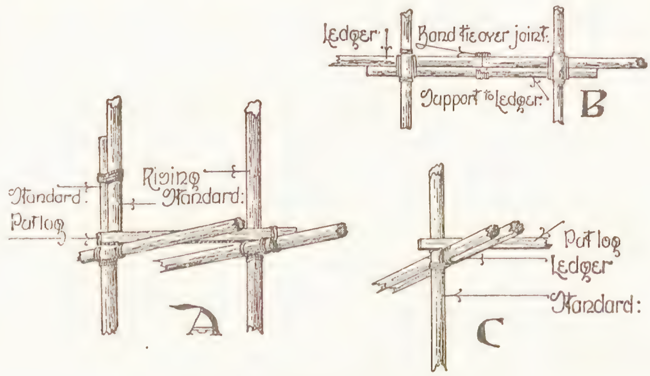


Fig. 159.—Details of scaffolding.

It is customary in England to form scaffolding on both sides of the wall, though in America and in Scotland the bricklayers and masons work from the inside of the wall only.

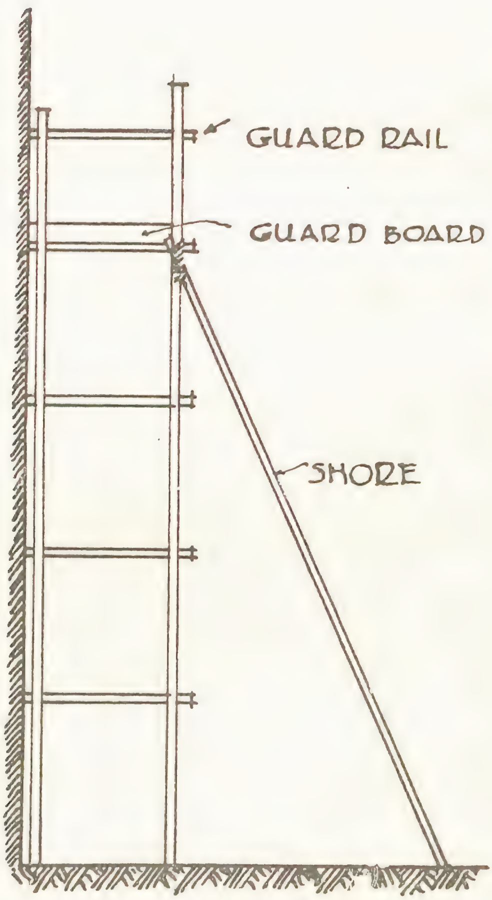


Fig. 160.—Masons' scaffolding.

STAGINGS

Where support is required for extremely heavy materials, such as large blocks of masonry, the lower portion of the scaffolding must be formed of squared timbers of the requisite dimensions, when it is known as a staging. These stagings form an elevated platform, and are constructed of two frames, an inner and an outer, having 9 × 9-inch uprights standing on 9 × 9-inch sleepers and supporting 9 × 9-inch heads. Across these heads from one frame to another are run 2 × 10-inch joists, over which 9 × 3-inch boarding is laid. The frames are braced apart by 2 × 7-inch diagonal cross braces, and the upper angles, formed

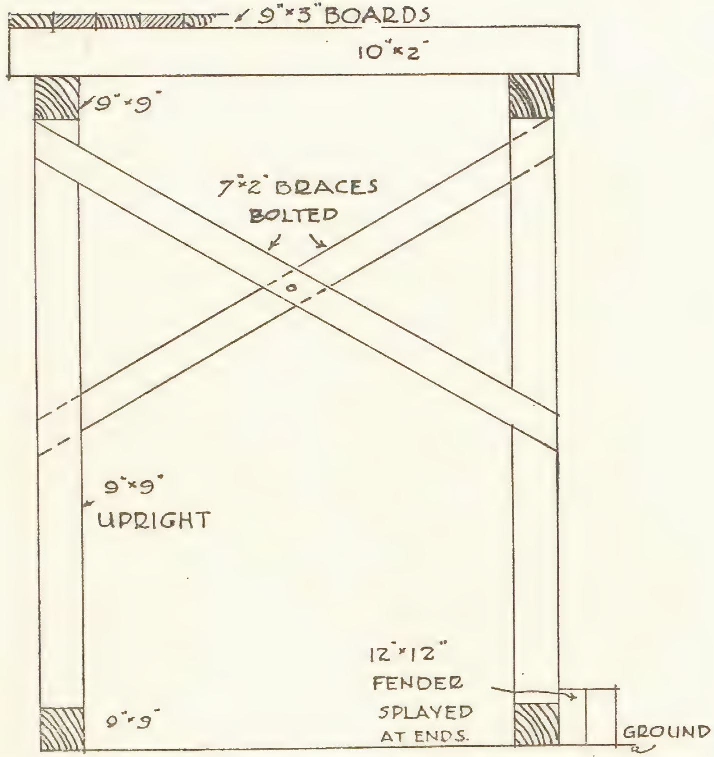


Fig. 161.—End elevation of staging.

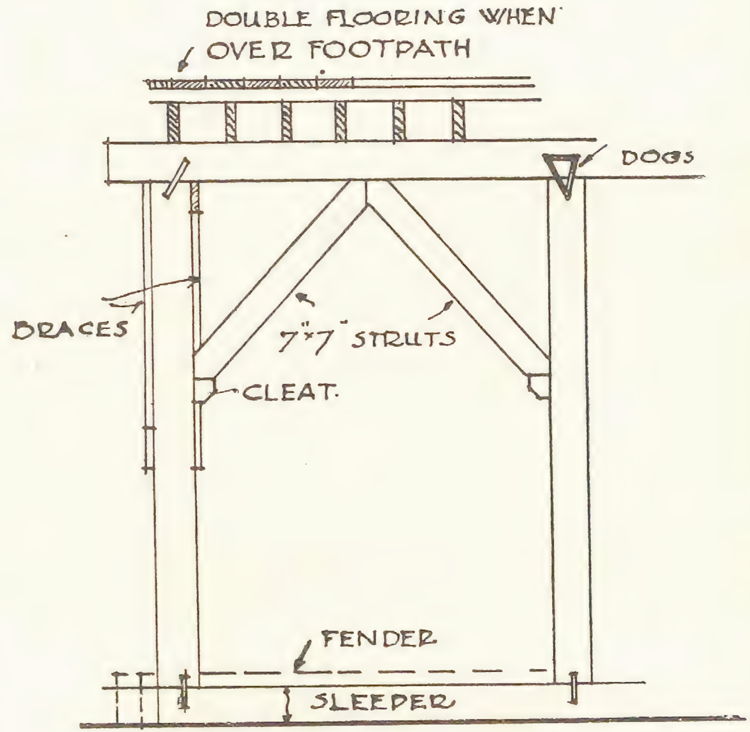


Fig. 162.—Side elevation of staging.

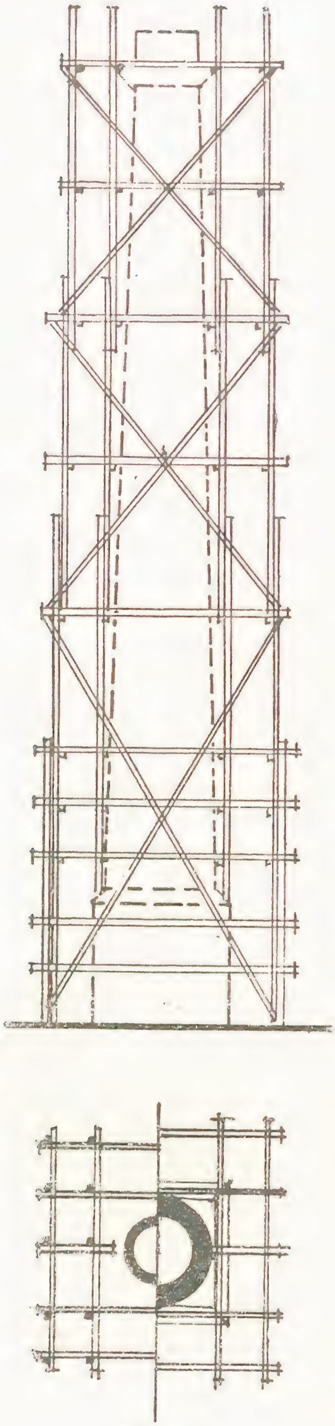


Fig. 163
Chimney scaffold.

by the 9 × 9-inch uprights in the 9 × 9-inch heads, are strengthened by 7 × 7-inch struts, meeting at the top in the centre of each bay and supported at the feet with cleats. Should further stiffening be required, the outer framework may be strengthened with raking shores, having their feet not less than 10 feet away and their heads under the top platform.

Adjustable steel staging is now widely used. It can be rapidly erected and adjusted for span.

CHIMNEY SCAFFOLD

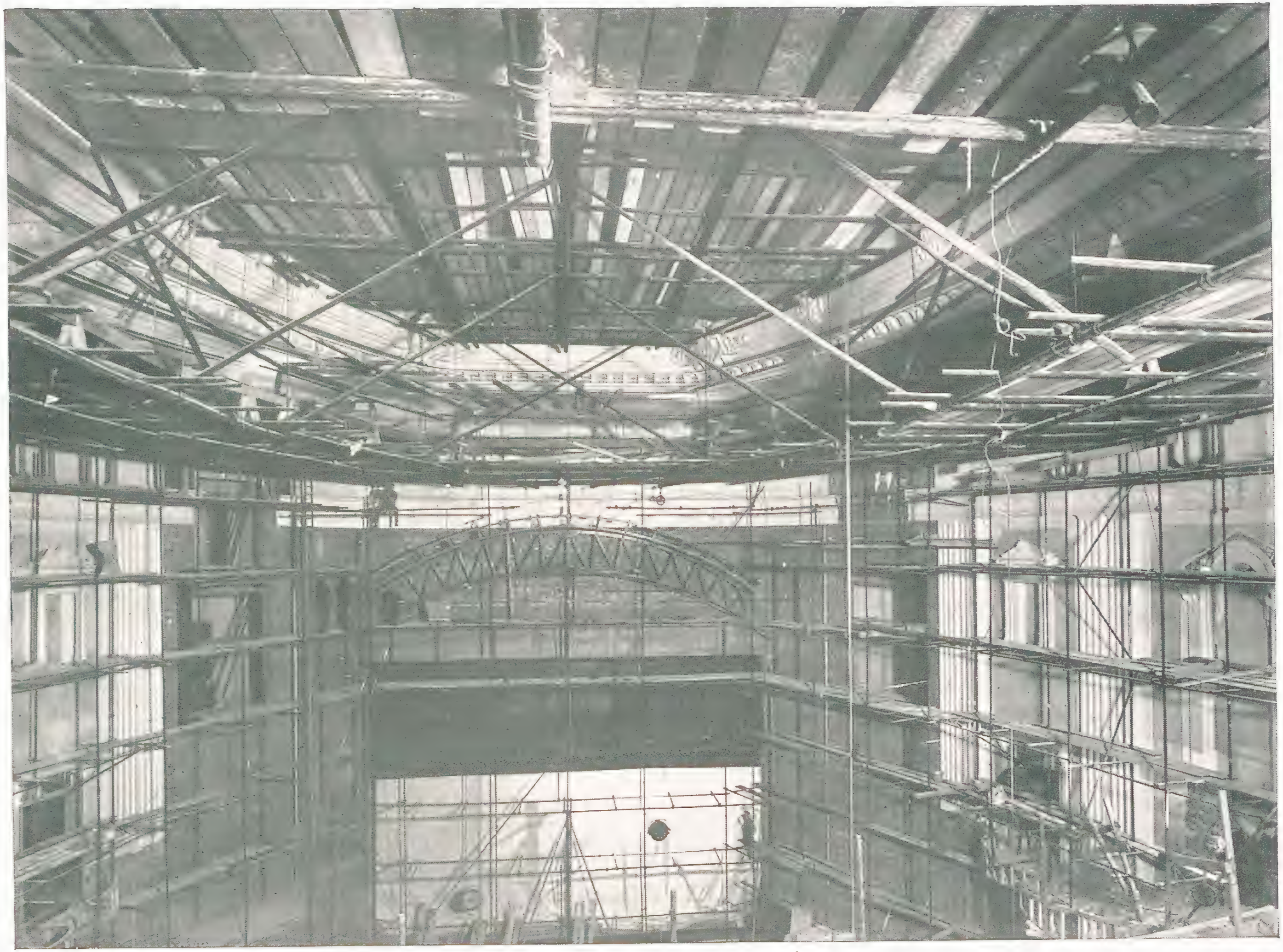
Tall chimneys are frequently built from internal scaffolding, which is raised as the work proceeds. The standards for internal scaffolding are supported by bearers rested on setbacks on the interior of the chimney. For access and delivery of materials to the platform a hinged trap door is formed in the centre of the platform.

Tall chimneys are also built from scaffolding erected externally, as where the walls are of greater thickness than 1 foot 10 inches, the external jointing cannot be properly finished from the inside. These scaffoldings consist of an inner and an outer framework. The lower standards are embedded in the ground, and the inner standards are rested on sleepers. The hoisting tackle and ladders are fixed externally, and the outer standards should be carried up well above the top of the chimney to provide attachments for hoists. The stiffenings of these scaffoldings depend to a great extent upon the cross braces, and these are lashed across from standard to standard, as in the ordinary scaffolding, but a new cross bracing should be started at every second ledger.

SPIRE SCAFFOLDING

Spire scaffolds rest on the tower below, and are started by a standard at each angle, having ledgers lashed to them. From the base also these standards are inclined at an angle, lashed together with ledgers, beams being lashed across the angles in such a position as will provide clearance for the spire. On these beams the

METAL SCAFFOLDING TO CHURCH SPIRE.



SUSPENDED SCAFFOLDING. INTERIOR REDECORATION TO A MODERN CINEMA.

putlogs are laid, and over these again are laid the scaffold boards. The raking standards must be firmly spliced with fishplates and the cross braces securely lashed at every second stage. Spire scaffolds are constructed in sections as the work proceeds, and their removal requires experience, the timbers having to be lowered by hand, as the hoists are naturally removed with the upper timbers.

SADDLE SCAFFOLDS

Where some portion of the building which does not afford support to a scaffolding from the ground requires to be repaired, such as a chimney or a lantern on the roof of a building, a scaffolding known as the saddle scaffold is constructed.

Standards may be erected on each side of the building, and ledgers run between these across the roof, if the width of the building is not too great. The ledgers must be strongly braced to the standards by diagonal bracings, and there should be a shore attached to them also, but where the width of the building is too great to admit of this form of scaffolding, a framework of scaffold poles, with all necessary cross braces, etc., is laid on the roof, one on each side of the chimney or other portion of the building requiring to be repaired, in such a manner that the standards of the framework cross each other at the ridge, at which point they are lashed together. In this way a framework of scaffolding is hung from the ridge on either side, and rests on the roof.

From these frameworks upright standards of a convenient height to form the platform necessary to reach the work are run, and at that height horizontal ledgers are lashed to the standards. The platform is laid on these in the usual manner.

Another means of reaching not easily accessible points is to lay ladders upon the roof on either side of the work and to fix to these a special form of scaffolding appliance known as Cripples. These are wrought-iron brackets, each having double clips which fit over the rungs of the ladder; being fitted with a quadrant and pin they can be adjusted to any angle. Across these brackets are laid boards to form a platform to work on.

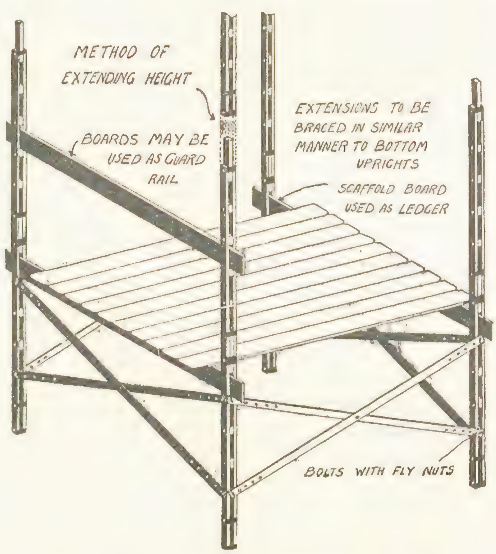


Fig. 164.—"Raprig" scaffolding staging.

"RAPRIG" SCAFFOLDING

Another type of scaffolding most useful for repair work, and particu-

larly for internal repairs, is the "Raprig" Scaffolding. This is a patented speciality supply, designed to save time and noise in erection. It is provided in units; each unit consists of four slotted uprights, each 7 feet 6 inches long, formed out of $3 \times 1\frac{1}{2}$-inch yellow or white deal, and $4 \times 3 \times 2$-inch blocks, each secured with $5\frac{1}{2} \times \frac{3}{8}$-inch bolts and nuts. There are also 12 stout wrought-iron bands, fastened with $3\frac{1}{2} \times \frac{1}{4}$-inch bolts and nuts, 8 braces 12 feet 6 inches long, 3×1-inch ends, bound and bored so that the distance between the uprights can be reduced or increased as required. The platform measures about 11×11 feet, and each end is fitted with a $\frac{3}{8}$-inch bolt and wing nut connected in the centre with a $2\frac{1}{2} \times \frac{5}{16}$-inch bolt and nut. The stage or platform may be fixed at any height up to 6 feet 10 inches with one unit, with two units to 14 feet 4 inches, three units 21 feet 10 inches, four units 29 feet 4 inches, five units 36 feet 10 inches, six units 44 feet 4 inches, and so on.

For ease in moving from one part of a building to another internally detachable wheeled legs are provided, and, if desired, these wheels may be fitted with rubber tyres.

Such a scaffolding as this is particularly useful for repair work and painting of ceilings having lofty roofs, such as in churches and cinemas.

This scaffolding may also be used externally when the standards are braced from the wall with grappling braces fitted with a hook at the end to engage into a driving eye. This driving eye is specially forged to be driven into the brickwork.

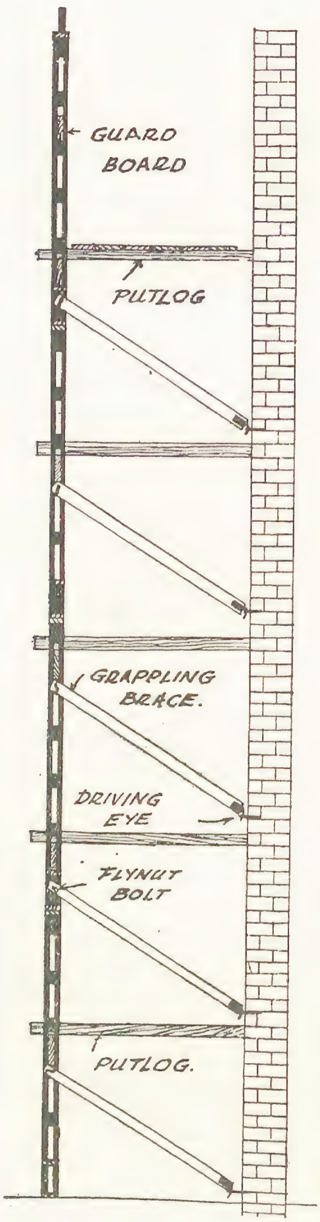


Fig. 165.
"Raprig" scaffolding.

DOME SCAFFOLDINGS

For interior painting and repairs to domes or buildings having high ceilings, such as churches and cinemas, the old-fashioned Dome Scaffolding formed of timber has been superseded to a great extent by the lighter forms of metal scaffolding.

It may be that it is required to continue the use of the floor of a building, such as a market hall for instance, during repairs or decorations to the roof, and a scaffolding suitable for such a purpose is formed of a working platform, supported by scaffold poles, the number of which may be reduced

PALMER'S TRAVELLING CRADLE.

A SUSPENDED SCAFFOLDING.

A SUSPENDED CRADLE SCAFFOLDING.

This type is especially used where it is required to leave the side walk unimpeded.

if the upper portion is very strongly braced by diagonal braces, which will stiffen the whole.

LADDER SCAFFOLDS

For repair work, where light, temporary scaffolding is required, these may be formed of ladders braced into the window openings, the platforms being supported on brackets bolted to the ladders. This is not a safe scaffold and should be used only for light jobs, and then with great caution.

SUSPENDED SCAFFOLDING

For interior repair and painting, and also for external repair, such as pointing and washing down, scaffoldings may be hung, either over steel framework in the roof, as for example the glass dome of the Royal Albert Hall, which was repaired by the use of Travelling Stages attached to the steel girders, or, in other and similar buildings, a combination of tubular and pole scaffolding is used, supported on a slung pole staging, suspended from the steel principals of the roof.

For light external repairs, the Travelling Cradle supersedes all other forms on account of the ease with which it can be raised and lowered, and its particular serviceability at rounded corners of buildings. In such positions the cradle is hung from a steel rail overhead, by which means it can be caused to travel horizontally as well as being raised and lowered.

The cradle itself is only 6 feet 6 inches long, which provides sufficient space for two men to work in, though one man can work it if required. It weighs less than $\frac{3}{4}$ cwt., and a continuous track can be fixed if required.

CANTILEVER SCAFFOLDING

Where it is required to use the pavement under a building, the lower portion of which has been completed, or where repair work has to be carried out to the upper portion of the building, a form of scaffolding known as the Cantilever Scaffolding is used. This scaffolding rests on beams projecting out of windows at a convenient height below the portion of building to which the work is to be carried out. The inner end of the cantilever within the building must be studded from the ceiling or beam-work of the room. Across the beams are run horizontal ties to which the standards are lashed. The usual ledgers are lashed to the standards, and putlogs connect the framework to the building in the usual manner on which the platforms are laid as the work proceeds.

STEEL SCAFFOLDING

Metal scaffolding may be used in all the positions and for the various purposes where wood scaffolding is used, and it has a considerable advantage, in that it is much more easily handled, as the standard lengths are

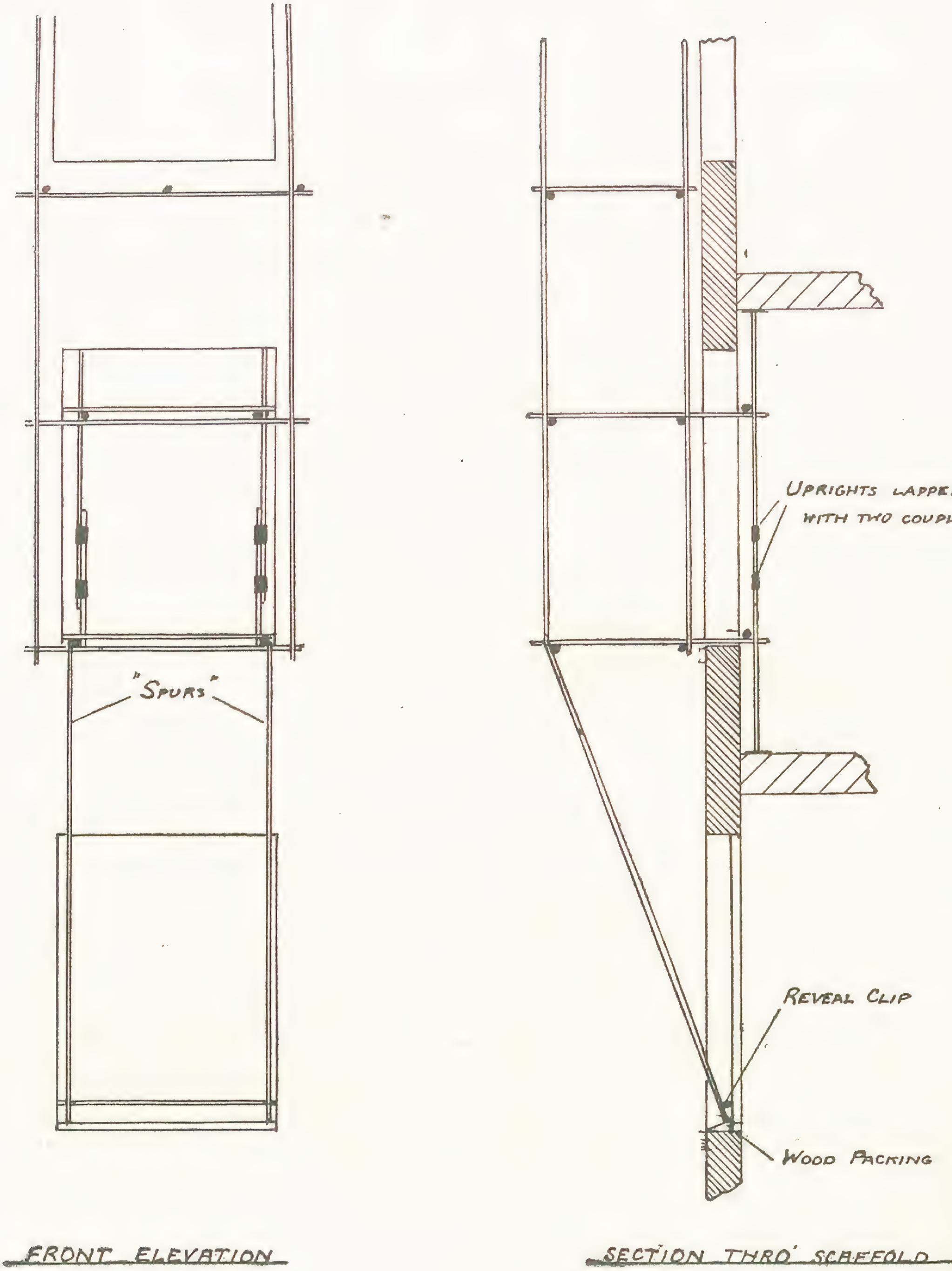
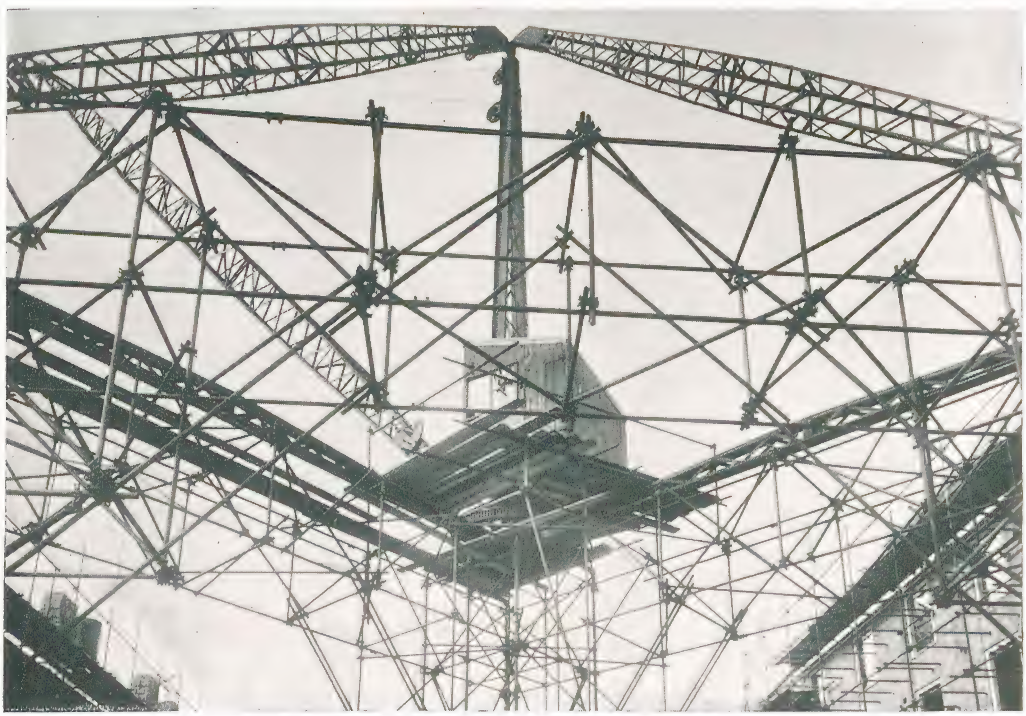


Fig. 166.—Cantilever steel scaffolding.

STEEL SCAFFOLDING.
(Courtesy of Mills Steel Scaffolding Co. Ltd.)

STEEL SCAFFOLDING FOR REINFORCED CONCRETE.



STEEL SCAFFOLDING FOR GANTRY TOWER.
(Both photos by courtesy of Mills Steel Scaffolding Co., Ltd.)

much shorter than scaffold poles. The time used in erection is much shorter than that required for wood scaffolding. It is also more economical in storage space when not in use.

It consists of standards which should be fixed every 6 feet apart for masons' scaffolding, and 8 feet to 10 feet apart for ordinary scaffolding.

There is an inner and an outer frame to each scaffolding, and the whole is securely fastened to the building by steel tubes fixed to a reveal pin, which is fastened to the window jambs or reveals to openings.

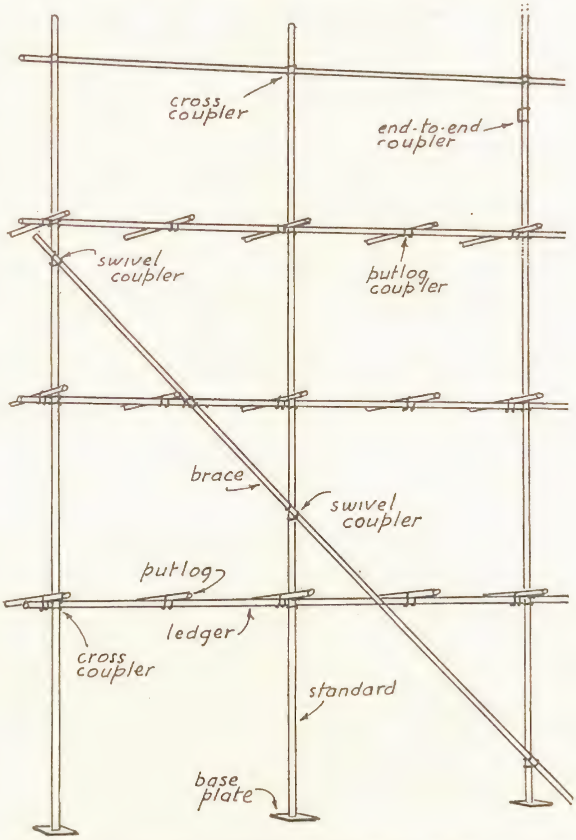


Fig. 167.—Tubular Scaffolding—showing names of parts.

FITTINGS

The ledgers and standards are coupled together with a 90-*degree clip* or *coupler*. Raking braces or struts, where required, are coupled to the standards with a *swivel clip* or coupler, which can be adjusted to any angle. The tubular putlogs are secured to the ledgers with *putlog clips*. For joining tubes to make long standards and ledgers the *end-to-end coupler* is used. A metal *sole-plate* fitting is fixed to the foot of each standard. The scaffold boards are laid on the putlogs in the normal way. The guard boards are attached to the standards with guard-board clips.

Strength.—Steel tubular scaffolding and fittings are made to British Standard No. 1139, which specifies strength requirements and tests.

As the tubes are of consistent strength the strength of a steel scaffold can be calculated in much the same way as any normal steel structure. In fact, steel scaffolding tubes are now widely used to build both temporary and permanent framed structures.

The ordinary size for scaffold tubes is called "two-inch," the nominal bore being $1\frac{1}{2}$ in. and the gauge 6 or 7. Tubes and fittings are heavily galvanised. A small diameter tube—"one-inch"—is used for decorators' scaffolds and storage racks, and the largest tube—"three-inch"—is used for supporting heavy loads.

Aluminium Scaffolding.—This tubular scaffolding is made from a

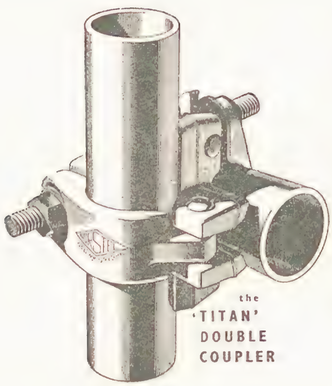


Fig. 168.

strong aluminium alloy. It is lighter than steel tubes and this is an advantage in handling and transport, and also in building tall scaffolds.

The reveal pin mentioned for attaching the scaffolding to the building is placed in an ordinary piece of tubing, which stands in a perpendicular position. A few turns of the bolt brings both ends into contact, and the putlog or transom is then coupled to the pin, thus securely tying in the scaffolding to the building.

GANTRIES

The most simple form of gantry is the builders' staging, which has already been described; the term however, is now extended to include any temporary structure used in building, having one working platform, either for the support of scaffolding and materials, or for the support of cranes.

The three types of gantries best known are: the Platform, the Traveller, and the Derrick Tower Gantries.

The Platform Gantry is usually constructed over footpaths which have to be kept open for the public. At the same time it affords storage room for materials used in the building, and on it are mounted the hoists for unloading. Ten by ten-inch sleepers are laid along the pathway to form a base, and 10 × 10-inch standards are mounted on them, supporting 10 × 10-inch beams, with 7 × $2\frac{1}{2}$-inch joists running from these towards the building. Over the 7-inch joists the planks are laid which form the flooring. A close-boarded fanguard is formed behind 4 × 4-inch studs, fixed at an angle to the upright standards to prevent materials falling below. Where materials are not delivered on to the platform, this fanguard is replaced by a handrail fixed 3 feet above the platform.

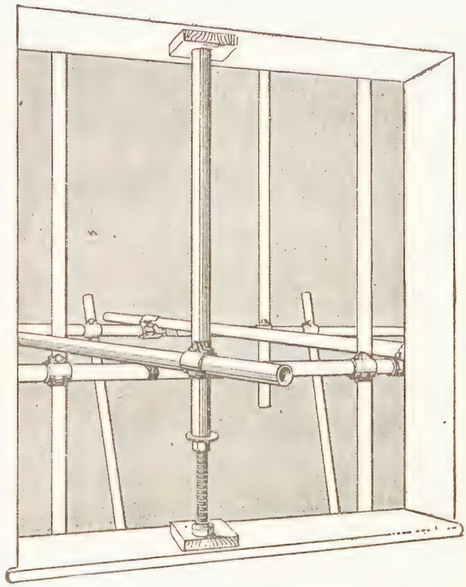


Fig. 169.—Reveal pin.

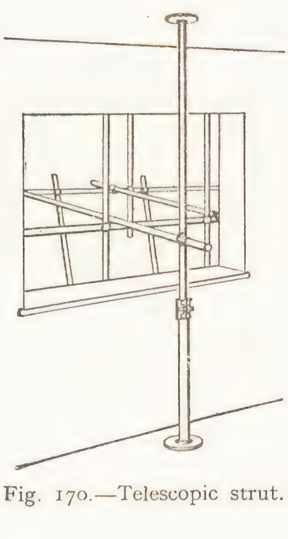


Fig. 170.—Telescopic strut.

The Traveller Gantry is a platform gantry in which the platform is replaced by rails, along the top of which a movable carriage runs. On this

a crab or winch is mounted, movable from side to side of the gantry. There are thus two movements afforded to the winch, longitudinal and transverse. This type of gantry is made of any length required, and up to 50 feet in width.

The timber of the gantry is of the following design and scantling: 12 × 12-inch sleepers, 12 × 12-inch uprights, and 12 × 12-inch heads; diagonal struts 7 × 7 inches, and raking struts 7 × 2 inches fixed to 6 × 6-inch uprights driven into the ground. The joints of the sleepers and heads to the uprights are dogged. Steel framed gantries are now used instead of timber gantries in most cases.

Movable Gantries are formed of frames to support travellers. These frames are made out of baulk timber, and are framed and bolted together, having at their base two 6 × 12-inch timbers, between which the wheels are fixed. These wheels run on rails carried by sleepers let into the ground. The traveller is carried on trussed beams, extending between the two frameworks last described. On these trussed beams are rails on which the traveller runs. The height of the frame is 18 feet and the distance apart up to 20 feet.

This type of gantry is more often met with in engineering than in building work.

The Derrick Tower Gantry.—This form of gantry is now regarded as out of date, having been almost entirely superseded by a lighter form of steel crane which works from the ground in erecting the frame of steel buildings.

When the steel is in position the cranes are raised and placed on the topmost steelwork.

The derrick tower gantry is formed by building three towers connected at the top by trussed beams on which is laid a platform. On this the crane works, being pivoted so that it can reach any part of the building operations. Three-tower gantries used to be constructed of heavy timbers, but steel framed gantry towers have displaced them in modern building. The steel towers are made in sections for rapid erection and ease of transport. A four-tower gantry is shown in Fig. 174. The crane is placed directly over one of the towers; this is called the crane or king tower, and to provide additional support for the extra weight of the derrick it should have a central standard in addition. The three towers are tied together by 1½-inch steel ties, running from the bottom of one tower to the top of the other. In soft soils the feet of the tower should be built up on concrete foundations. The platform is fenced round with a platform at the usual height. The crane consists of an upright member known as the mast, held in position by two stays running to the opposite corners of the triangular staging, and to the bottom of the mast there is connected by hinge joints the gib. Over the top of this there runs a chain through a pulley to a steam winch. This chain and pulley are used for raising and lowering the gib. For raising the loads a steel rope is passed over

the pulleys, one at the end of the gib, and the other at the end of the mast.

LIFTING TACKLE AND CRANES

Pulleys.—The gin wheel is the simplest lifting device. It is simply a grooved pulley wheel with a shaft mounted on bearings attached to a frame. There is a hook at the top by which the wheel can be suspended from any suitable point on the scaffolding. The gin wheel is suitable for hoisting a bucket of sand or a basket of rubbish. The rope runs over the wheel, but there is no mechanical advantage—the pull exerted must be rather more than the load hoisted to overcome friction.

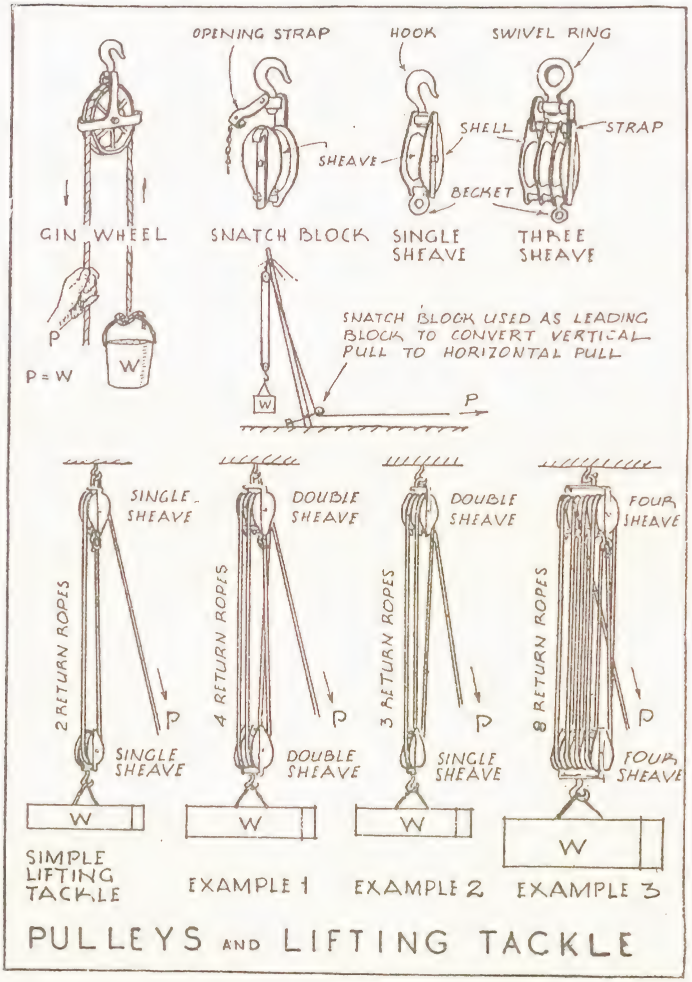


Fig. 171

Lifting Tackle consists of two pulley blocks, with either single sheaves or more according to the mechanical advantage desired. The examples illustrated in Fig. 171 shows how the rope is arranged for various combinations. By using lifting tackle we gain a mechanical advantage at the price of speed. The more sheaves in the blocks the greater the weight we can lift with a given pull but the slower the hoisting speed.

The pull required is calculated by the following formula, which allows for friction losses :

$$P = \frac{W}{G}(1 + fn)$$

Where P is pull required on running end of rope,

W is load to be lifted in the same units as P,

G is number of returns of rope at the travelling block,
n is the number of sheaves top and bottom,
f is a coefficient of friction, varying from $\frac{1}{5}$th to $\frac{1}{10}$th according to condition of tackle. For tackle in good condition $\frac{1}{10}$th may be assumed.

Example.—If a lifting tackle has two double-sheave blocks with four

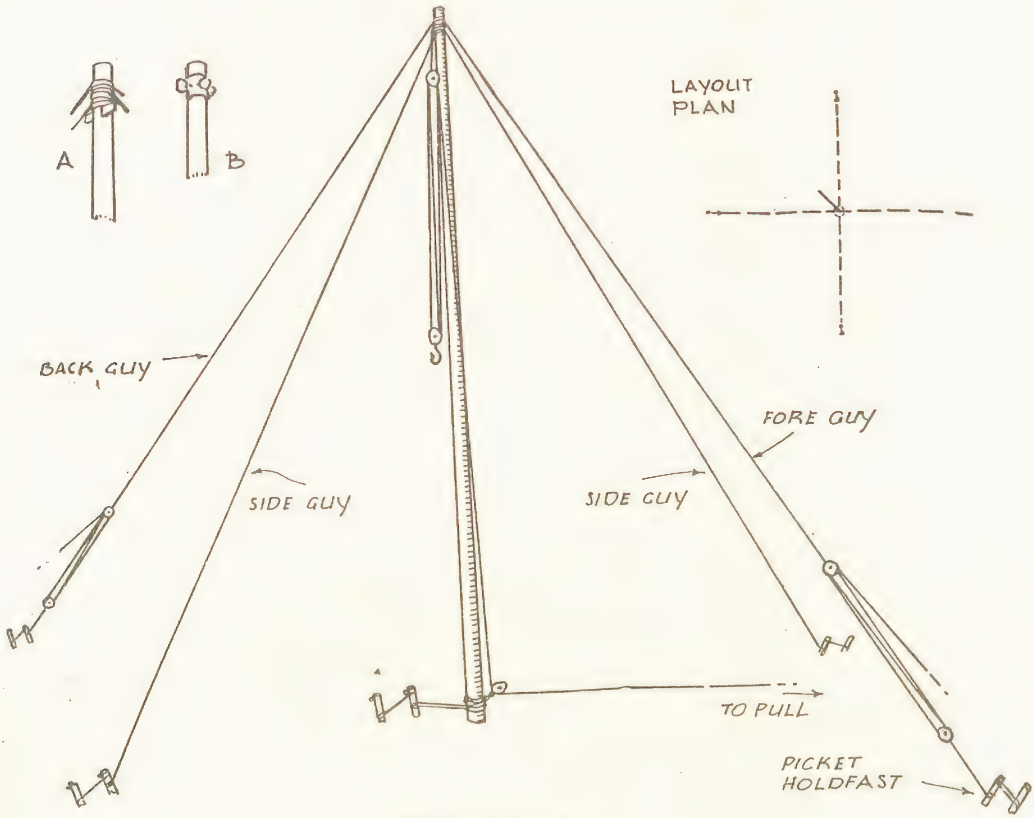


Fig. 172.—Pole derrick.

return ropes, and it is required to lift a load of 5 cwt., what pull in lb. is required on the running end of the rope?

$$5 \text{ cwt.} = 560 \text{ lb.} = W$$

From the formula given above,

$$P = \frac{560}{4}\left(1 + \frac{1}{10} \times 4\right) = 140 \times 1{\cdot}4 = 196 \text{ lb.}$$

It will be seen from this that 56 lb. of the pull (196 − 140) is required to overcome friction losses.

This calculation is of practical importance in selecting a suitable lifting tackle for any load.

Makers of pulley blocks, ropes, and wire ropes issue tables of the strength of their products. These apply to the new products and allowance should be made for wear.

Derricks and Shear Legs.—The pole derrick illustrated in Fig. 172 is suitable for hoisting light loads such as steel joists and trusses, raking shores, etc. For heavier loads steel derricks should be used. The radius through which a load can be moved is very small.

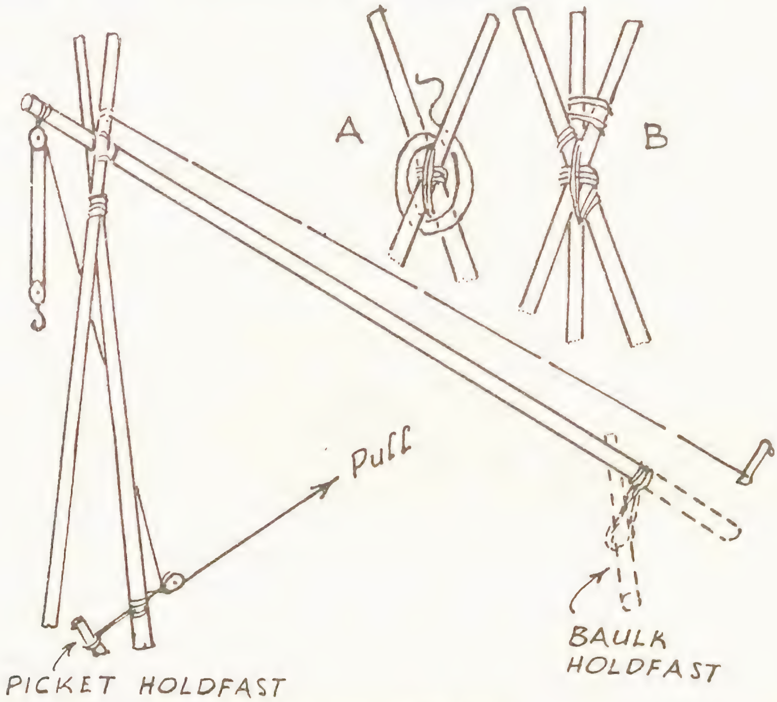


Fig. 173.—Shear legs.

The shear legs illustrated in Fig. 173 are also suitable for light loads. They can be fixed to a scaffold for hoisting brick skips, barrows, joists, etc., and are also used over excavations for hoisting soil or lowering sewer pipes. Steel tubular tripods are, however, now largely used for the latter purpose.

Small Hoists and Cranes.—There are several modern hoists which are more convenient in use than the older derrick pole and shear leg hoists. The "Scafco" hoist illustrated in Fig. 174 can be attached to the scaffolding. It can be fitted either with a barrow platform or a tipping skip for concrete.

The Super Twelve crane illustrated in Fig. 175 is a portable crane with a small slewing radius through a complete circle. It is useful for hoisting light loads where no scaffolding is available. The Super Twenty crane, also illustrated in Fig. 175, is particularly useful for loading and unloading up to 1 ton.

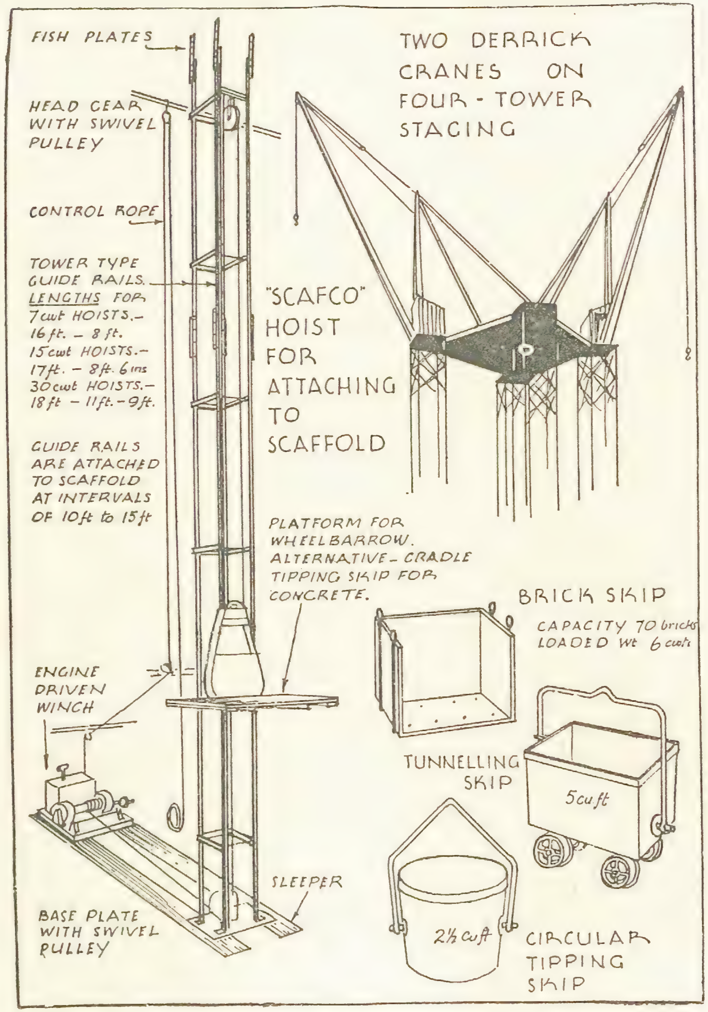


Fig. 174.

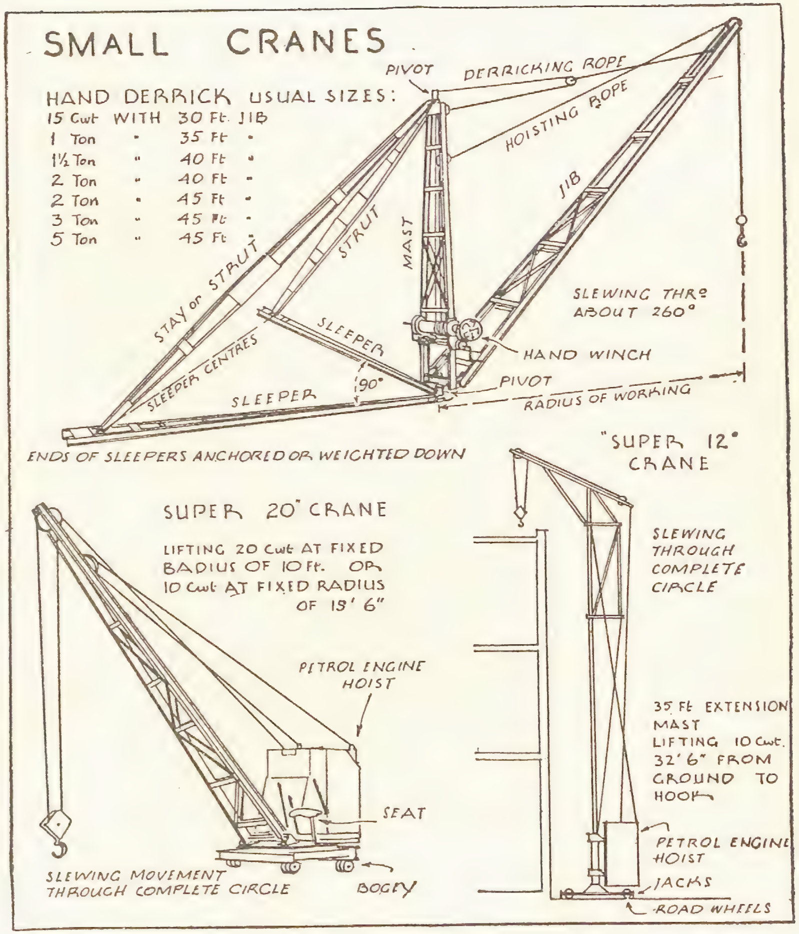


Fig. 175.

Winches, either hand- or power-operated, are useful for hoisting or pulling. They can be used in connection with derrick poles and shear legs. The rope must run horizontally to the winch. This is arranged by passing it through a snatch block as in Fig. 171. The winch must be secured against overturning.

Scotch Derrick Crane.—This is illustrated in Fig. 175. It is made in various sizes to hoist from 15 cwt. to 5 tons. The jib slews through about 260 degrees. It can be hand- or power-operated. If erected temporarily on the ground, the sleepers should be weighted down with loose bricks on planking. These stability weights are specified by the makers. On a steel derrick staging the sleepers are anchored with strong wire ropes, the ends of which are secured to stacks of bricks at the foot of the towers.

For hoists of considerable height the ***Tower Derrick*** is now widely used. This has a mast pivoted in a steel-framed tower. The jib load is counterbalanced with weights extending at the back.

REGULATIONS

THE BUILDING (SAFETY, HEALTH AND WELFARE) REGULATIONS, 1948

Explanatory Note.—These Regulations supersede the Building Regulations 1926 to 1931. They provide a code of rules for operations of the kinds described in Regulation 2, which include the construction, structural alteration, repair or maintenance of a building, the demolition of a building and the preparation for, and laying the foundation of, an intended building.

The revoked Regulations were confined to premises on which power-driven machinery was temporarily used for the construction of a building or for any addition to the structure of an existing building.

The present Regulations are not limited in this way, and also contain in Part VI new provisions with regard to health and welfare.

Part I—Interpretation and General—is omitted in this reproduction. Copies of the Regulations are obtainable from H.M. Stationery Office, or through any bookseller.

PART II.—SCAFFOLDS AND MEANS OF ACCESS

Provision of scaffolds and means of access

5. Suitable and sufficient scaffolds shall be provided for all work that cannot safely be done on or from the ground or from part of the building, or from part of a permanent structure or from a ladder or other available means of support, and sufficient safe means of access shall so far as is reasonably practicable be provided to every place at which any person has at any time to work.

Supervision of work and inspection of material

6. No scaffold shall be erected or be substantially added to or altered or be dismantled except under the immediate supervision of a competent person and so far as possible by competent workmen possessing adequate experience of such work. All material for any scaffold shall be inspected by a competent person on each occasion before being taken into use.

Construction and material

7.—(1) Every scaffold and every part thereof shall be of good construction, of suitable and sound material and of adequate strength for the purpose for which it is used.

(2) Sufficient material shall be provided for and shall be used in the construction of scaffolds.

(3) Timber used for scaffolds shall be of suitable quality, be in good condition, have the bark completely stripped off, and not be painted or treated in any way so that defects cannot easily be seen.

(4) Metal parts used for scaffolds shall be of suitable quality and be in good condition and free from corrosion or other patent defect likely to affect their strength materially.

Defective material

8.—(1) No defective material or part which cannot be satisfactorily repaired shall be used for a scaffold. Defective parts or materials which can be satisfactorily repaired shall not be used until they are so repaired.

(2) No rope which is defective whether through contact with an acid or other corrosive substance or otherwise shall be used.

(3) All materials and parts for scaffolds shall when not in use be kept under good conditions and apart from any materials or parts unsuitable for scaffolds.

Maintenance

9.—(1) All scaffolds shall be properly maintained, and every part shall be kept so fixed, secured or placed in position as to prevent so far as is practicable accidental displacement.

(2) No scaffold or part of a scaffold shall be partly dismantled and remain in such a condition that it is capable of being used unless either—

(*a*) the scaffold continues to comply and would, if used, comply with these Regulations, or

(*b*) if the scaffold or part thereof would, if used, not comply with these Regulations, a prominent warning notice indicating that the scaffold or part thereof is not to be used is affixed near any point at which the scaffold or part, as the case may be, is liable to be approached for the purpose of use.

Standards, uprights, ledgers and putlogs

10.—(1) Standards or uprights of scaffolds shall be—

(*a*) where practicable vertical or slightly inclined towards the building; and

(*b*) fixed sufficiently close together to secure the stability of the scaffold having regard to all the circumstances.

(2) The displacement of the foot of any standard or upright shall, unless prevented in some other sufficient way, be prevented either—

(*a*) by sinking the standard or upright a sufficient distance into the ground; or

(*b*) by placing the standard or upright on an adequate base plant in a manner to prevent slipping.

(3) Ledgers shall be as nearly as possible horizontal and shall be securely fastened to

the uprights or other means of support or suspension by bolts, dogs, ropes or other efficient means.

(4) Where two ledgers are connected together the connection shall be secure and in the case of timber ledgers not connected together at an upright or point of suspension both ledgers shall be connected to a separate slicing ledger of adequate strength spanning between and properly secured to the uprights or points of suspension on opposite sides of the connection of the ledgers.

(5) Putlogs shall be straight or approximately straight and shall be securely fastened to the ledgers or the standards or uprights, except in the case of a timber putlog so shaped and placed that fastening is not necessary to prevent its displacement. Putlogs which have one end supported by a wall shall have at that end a flat supporting surface of sufficient area. Nails shall not be used for fastening putlogs.

(6) The distance between two consecutive putlogs or other supports on which a platform rests shall be fixed with due regard to the anticipated load and the nature of the platform flooring. As a general rule the distance with single planking shall not exceed 3 feet 3 inches with planks $1\frac{1}{4}$ inches in thickness, 5 feet with planks $1\frac{1}{2}$ inches in thickness, or 8 feet 6 inches with planks 2 inches in thickness.

Ladders used as uprights and ladder scaffolds

11.—(1) Ladders serving as uprights of scaffolds shall—

(*a*) be of adequate strength; and

(*b*) (i) be sunk into the ground to such a depth as to secure stability, or be placed on sole plates or boards so that the two uprights of each ladder rest evenly on the base; and

(ii) be secured to prevent slipping.

(2) Ladder scaffolds shall not be used unless the work is of such a light nature and the material required for the work is of such that this type of scaffold can be used with safety.

Support and stability of scaffolds

12.—(1) Every scaffold shall be securely supported or suspended and shall where necessary be sufficiently and properly strutted or braced to ensure stability and, unless it is properly designed and constructed as an independent scaffold, shall be rigidly connected with the building.

(2) All structures and appliances used as supports for scaffolds, working platforms, gangways or runs shall be of sound construction, have a firm footing or be firmly supported, and shall where necessary be sufficiently and properly strutted or braced to ensure stability.

(3) Any travelling scaffold which can be moved on wheels or skids shall, unless it is a suspended or slung scaffold, be—

(*a*) constructed with due regard to stability, and, if necessary for stability, adequately weighted at the base;

(*b*) used only on a firm and even surface, not so sloping as to involve risk of instability of the scaffold or any load thereon;

(*c*) adequately secured to prevent movement when any person is working upon it;

(*d*) moved only be the application of force at or near the base.

(4) Loose bricks, drain pipes, chimney pots or other unsuitable material shall not be used for the construction or support of scaffolds save that bricks or small blocks may, if they provide a firm support, be used to support a platform not more than two feet above the ground or floor.

Gear for suspension of scaffolds

13.—(1) Chains, ropes and lifting gear used for the suspension of scaffolds shall be of sound material, adequate strength and suitable quality, and in good condition.

(2) No rope other than a wire rope shall be used for the suspension of a scaffold, but this requirement shall not apply in the case of a suspended scaffold which is raised or lowered otherwise than by means of winches or in the case of equipment being used for the purposes of a suspended scaffold in accordance with Regulation 18.

(3) Chains, ropes and metal tubes used for the suspension of a scaffold other than a suspended scaffold shall be properly and securely fastened to safe anchorage points and to the scaffold ledgers or other main supporting members, and shall be so positioned as to ensure stability of the scaffold, be approximately vertical and be kept taut.

(4) Every scaffold suspended by means of ropes or chains shall be secured to prevent undue horizontal movement while it is used as a working platform.

Cantilever, jib, figure and bracket scaffolds, etc.

14.—(1) No cantilever or jib scaffold shall be used unless it is adequately supported, fixed and anchored on the opposite side of the support, has outriggers of adequate length and cross-section and is where necessary sufficiently and properly strutted or braced to ensure rigidity and stability.

(2) No working platform resting on bearers let into a wall at one end and without other support shall be used unless the bearers are of adequate strength, pass through the wall and are securely fastened on the other side.

(3) No figure or bracket scaffold supported or held by dogs, spikes, or similar fixings liable to pull out of the stonework or brickwork in which they are gripped or fixed shall be used.

Scaffolds supported by building

15. No part of a building shall be used as support for part of a scaffold unless it is of sound material and sufficiently stable and of sufficient strength to afford safe support. Overhanging eaves gutters shall not be used as such supports unless they have been specially designed as walkways and are of adequate strength.

Suspended scaffolds raised or lowered by means of winches

16. Suspended scaffolds raised or lowered by means of winches shall not be used unless—

(*a*) outriggers are—
  (i) of adequate length and strength and properly installed and supported;
  (ii) installed horizontally;
  (iii) properly spaced in relation to the putlogs or deck irons;
  (iv) securely fixed to the building by anchor bolts or other equivalent means, or where such fixing is not reasonably practicable, adequately and securely anchored at the inner ends;
  (v) provided with adequate stops at their outer ends; and

(*b*) the points of suspension are an adequate horizontal distance from the building face; and

(*c*) the suspension ropes are—
  (i) of good construction, sound material, adequate strength, and free from patent defect;
  (ii) securely attached to the outriggers or other supports and to the winch drums;
  (iii) of such length that at the lowest position of the platform there are at least two turns of rope on each winch drum; and

(*d*) the platform is—
  (i) not less than 25 inches wide,
  (ii) so arranged or secured that, at each working position, the edge of the platform (whether of the normal platform or of an extension thereof towards the

building face as the case may be) is as close as practicable to the building face, but so that where workmen sit at the edge of the platform to work the edge may be not more than 12 inches from such face.

Other suspended scaffolds

17. Suspended scaffolds other than scaffolds raised or lowered by means of winches shall not be used unless—

(*a*) outriggers are—
(i) of adequate length and strength and properly installed and supported;
(ii) firmly anchored at the inner ends;
(iii) securely fastened to any ballast or counterweight; and

(*b*) the points of suspension are an adequate horizontal distance from the building face; and

(*c*) the platform is—
(i) not less than 17 inches wide;
(ii) suspended by ropes or chains which are spaced not more than 10 feet 6 inches apart, are maintained in tension and are properly and securely fastened; and
(iii) suspended so as to prevent tipping or tilting of the platform; and

(*d*) the suspension ropes or chains are of good construction, sound material, adequate strength, and free from patent defect; and

(*e*) there are devices provided and used where necessary to keep the platform at a sufficient distance from the wall when persons have to work in a sitting position;

Provided that paragraph (*c*) (ii) of this Regulation shall not apply in the case of a scaffold which is securely suspended from fixed anchorages and has a platform more than 25 inches wide supported on metal bearers properly and securely connected to raising and lowering tackle (being wire rope or chain tackle such as automatically sustains the load).

Skips, buckets, baskets, boatswain's chairs, etc.

18.—(1) A skip, bucket, basket, boatswain's chair or similar equipment shall not be used for the purposes of a suspended scaffold except in special circumstances where the work is of such short duration as to make the use of a suspended scaffold unreasonable or where the use of a suspended scaffold is not reasonably practicable and shall only be so used under the supervision of a responsible person.

(2) Such equipment shall not be used for the purposes of a suspended scaffold unless—

(*a*) the equipment including the suspension ropes or chains and their means of support are of good construction, sound material, adequate strength and free from patent defect and the ropes or chains are securely attached; and

(*b*) suitable measures are taken to prevent spinning or tipping and to prevent any occupant from falling therefrom.

(3) No skip, bucket or basket shall be used for the purposes of a suspended scaffold unless it is—

(*a*) at least 2 feet 6 inches deep; and

(*b*) either constructed wholly of suitable metal or carried by two strong bands of suitable metal which are properly fastened and continued round the sides and bottom.

Trestle scaffolds

19.—(1) No trestle scaffold shall be used—

(*a*) if constructed with more than three tiers; or

(*b*) if it has a working platform more than 15 feet above the ground or floor or other surface upon which the scaffold is erected

(2) No trestle scaffold shall be erected on a scaffold platform unless—

(*a*) the width of the platform is such as to leave sufficient clear space for the transport of materials; and

(*b*) the trestles or uprights are firmly attached to the platform and adequately braced to prevent displacement.

(3) No trestle scaffold shall be erected on a suspended scaffold.

Inspection of scaffolds

20.—(1) Subject to the provisions of this Regulation no scaffold shall be used unless—

(*a*) it has been inspected by a competent person within the immediately preceding seven days; and

(*b*) it has been inspected by a competent person since exposure to weather conditions likely to have affected its strength or stability or to have displaced any part; and

(*c*) a report of the results of any such inspection in the prescribed form and including the prescribed particulars and signed by the person making the inspection has been entered into or attached to the prescribed register:

Provided that paragraph (*a*) shall not apply in the case of a scaffold no part of which has been erected for more than seven days, and paragraph (*c*) shall not apply to a ladder scaffold, a trestle scaffold or a scaffold from no part of which a person is liable to fall more than 6 feet 6 inches.

(2) Paragraph (1) hereof shall not require a scaffold to be inspected by reason only that it has been added to, altered, or partly dismantled.

(3) In the case of a site where the employer for whom the inspection was carried out has reasonable grounds for believing that the operations will be completed in a period of less than six weeks, the provision in this Regulation requiring that a report shall have been made and signed shall be deemed to have been satisfied if the person in charge of the operations carried on by that employer at such site had himself carried out the inspection and is a person competent so to do and if, within one week of the date of the inspection, he informs his employer in writing that the scaffold was inspected by him and that he found it in good order, or observed certain defects as the case may be, and the date of such inspection and the results thereof together with the name of the person making the inspection are entered in the prescribed register.

Scaffolds used by workmen of more than one employer

21. Where a scaffold or part of a scaffold is to be used by or on behalf of an employer other than the employer for whose workmen it was first erected, the first-mentioned employer shall, before such use, and without prejudice to any other obligations imposed upon him by these Regulations, take express steps, either personally or by a competent agent, to satisfy himself that the scaffold or part thereof is stable, that the materials used in its construction are sound and that the safeguards required by these Regulations are in position.

Working platforms (including working stages)

22. Every working platform from which a person is liable to fall more than 6 feet 6 inches shall be—

(*a*) closely boarded, planked, or plated;

(*b*) at least 25 inches wide if the platform is used as a footing only and not for the deposit of any material;

(*c*) at least 34 inches wide if the platform is used for the deposit of material;

(*d*) at least 42 inches wide if the platform is used for the support of any higher platform;

(*e*) at least 51 inches wide if the platform is one upon which stone is dressed or roughly shaped;

(*f*) at least 59 inches wide if the platform is used for the support of any higher platform and is one upon which stone is dressed or roughly shaped:

Provided that—

(i) requirement (*a*) of this Regulation shall not apply to a platform consisting of open metalwork having interstices none of which exceeds 6 square inches in area, if there is no risk of persons below such platform being struck by tools or other objects falling through the platform;

(ii) requirement (*a*) of this Regulation shall not apply to a platform which is part of the permanent fixed equipment of a building and the boards, planks or plates of which are so secured as to prevent their moving and so placed that the space between adjacent boards, planks or plates does not exceed 1 inch, if there is no risk of persons below such platform being struck by tools or other objects falling through the platform;

(iii) requirements (*b*) to (*f*) of this Regulation shall not apply to a working platform which is at least 17 inches wide, and is on the outside of any sloping roof;

(iv) requirements (*b*) and (*c*) of this Regulation shall not apply in the case of the platform of a suspended scaffold, or in the case of a platform not less than 17 inches wide being the platform of a ladder scaffold or of a trestle scaffold or being a platform under a roof which is supported by or suspended from roof members or the roof and which is used only by painters for the purpose of painting work in the vicinity of the roof, where in any such case the work is of such a light nature and the material required for the work is such that a platform less than 25 or 34 inches wide as the case may be can be used with safety, and the platform is not used for the support of any higher platform;

(v) requirements (*b*) and (*c*) of this Regulation shall not apply in the case of a temporary platform not less than 17 inches wide passing between two adjacent glazing bars of a sloping roof if the space between those bars does not admit of the platform being at least 25 inches wide and if the platform is used only for work in the vicinity of those bars;

(vi) requirement (*d*) of this Regulation shall not apply to the platform supporting the second tier of a trestle scaffold.

Boards and planks in working platforms, gangways and runs

23.—(1) Every board or plank forming part of a working platform or used as a toe-board shall be—

(*a*) of a thickness which is such as to afford adequate security having regard to the distance between the putlogs or standards; and

(*b*) not less than 8 inches wide or in the case of boards or planks exceeding 2 inches in thickness, not less than 6 inches wide.

(2) No board or plank which forms part of a working platform, gangway or run shall project beyond its end support to a distance exceeding four times the thickness of the board or plank unless it is effectively secured to prevent tipping, or to a distance which, having regard to the thickness and strength of the plank renders the projecting part of the plank an unsafe support for any weight liable to be upon it.

(3) Suitable measures such as the provision of adequate bevelled pieces shall be taken to reduce to a minimum the risk of tripping and to facilitate the movement of barrows where boards or planks which form part of a working platform, gangway or run overlap each other or are not a reasonably uniform thickness where they meet each other or owing to warping or for some other reason do not provide an even surface.

(4) Every board or plank which forms part of a working platform shall—

(*a*) rest securely and evenly on its supports, and

(*b*) rest on at least three supports unless, taking into account the distance between the supports and the thickness of the board or plank, the conditions are such as to prevent undue sagging.

(5) Where work has to be done at the end of a wall the working platform at such wall shall, wherever practicable, extend at least 24 inches beyond the end of the wall.

Guard-rails and toe-boards at working places

24.—(1) Subject to paragraphs (3), (4) and (5) of this Regulation, every side of a working platform or working place, being a side thereof from which a person is liable to fall a distance of more than 6 feet 6 inches, shall be provided with a suitable guard-rail or guard-rails of adequate strength, to a height of at least 3 feet above the platform or place and above any raised standing place on the platform, and with toe-boards up to a sufficient height being in no case less than 8 inches and so placed as to prevent so far as possible the fall of persons, materials and tools from such platform or place.

(2) The guard-rails and toe-boards used on a working platform or working place shall be placed on the inside of the uprights, and the space between any toe-board and the lowest guard-rail above it shall not exceed 27 inches.

(3) Guard-rails and toe-boards required by paragraphs (1) and (2) of this Regulation may be removed or remain unerected for the time and to the extent necessary for the access of persons or the movement of materials.

(4) On the side of a suspended scaffold facing the wall—

(*a*) guard-rails where required by this Regulation need not extend to a height of more than 27 inches above the platform if the work is impracticable with a guard-rail at a greater height;

(*b*) guard-rails and toe-boards shall not be required if the workers sit at the edge of the platform to work and ropes or chains affording all the workers a safe and secure handhold are provided.

(5) (*a*) The requirements of paragraphs (1) and (2) of this Regulation regarding toe-boards shall not apply to the platform of a ladder scaffold or of a trestle scaffold or where and in so far as the provision of a toe-board is impracticable on account of the nature or special circumstances of the work.

(*b*) The requirements of paragraphs (1) and (2) of this Regulation regarding guard-rails shall not apply to the platform of a ladder scaffold if a secure handhold is provided for full length of such platform or to the platform of a trestle scaffold when the platform is supported on folding trestles or step ladders.

(*c*) The requirements of paragraphs (1) and (2) of this Regulation shall not apply to a platform provided with suitable guard-rails which is on the outside of a sloping roof.

(*d*) The requirements of paragraphs (1) and (2) of this Regulation shall not apply to a temporary platform which is used only by erectors of structural steelwork or iron-work for the purposes of bolting-up, riveting or welding work of such short duration as to make the provision of a platform with guard-rails and toe-boards unreasonable if (i) the platform is at least 34 inches wide and (ii) there is adequate handhold and (iii) the platform is not used for the deposit of tools or materials otherwise than in boxes or receptacles suitable to prevent the fall of the tools or materials from the platform.

(*e*) The requirements of paragraphs (1) and (2) of this Regulation shall not apply to a temporary platform passing between two adjacent glazing bars of a sloping roof if those bars or the roof framework afford secure handhold for the full length of the platform, and the requirements of paragraphs (1) and (2) regarding toe-boards shall not apply as respects such platform where and in so far as the provision of a toe-board is impracticable on account of the nature or circumstances of the work.

(*f*) The requirements of paragraphs (1) and (2) of this Regulation shall not apply to a platform under a roof which is supported by or suspended from roof members or the roof and which is used only by painters for the purpose of painting work in the immediate vicinity of the roof, being work of such short duration as to make the provision of a platform with guard-rails and toe-boards unreasonable, if (i) there is adequate handhold at every working position and (ii) the material required for the work is such that the platform can be used with safety.

Working platform at building face and clearance of passage ways

25.—(1) Where work at the face of a building is done from a working platform the space between the face of the building and the working platform shall be as small as practicable so, however, that where workmen sit at the edge of the platform to work the space shall not exceed 12 inches.

(2) A clear passage way at least 17 inches wide shall be left between one side of any working platform and any fixed obstruction or deposited material.

Construction and use of gangways and runs

26.—(1) Every gangway or run from any part of which a person is liable to fall a distance of more than 6 feet 6 inches shall—

(*a*) be closely boarded, planked or plated;

(*b*) be at least 17 inches wide:

Provided that the requirement in paragraph (1) (*a*) shall not apply—

(i) to a gangway or run consisting of open metalwork having interstices none of which exceeds 6 square inches in area, if there is no risk of persons below such gangway or run being struck by tools or other objects falling through the gangway or run, or

(ii) to a gangway or run which is part of the permanent fixed equipment of a building and the boards, plates or planks of which are so secured as to prevent their moving and so placed that the space between adjacent boards, planks or plates does not exceed 1 inch, if there is no risk of persons below such gangway or run being struck by tools or other objects falling through the gangway or run.

(2) No gangway, run or working platform shall be used for the passage of materials unless it affords a clear passage way which is adequate in width for the passage of the materials without removal of the guard-rails and toe-boards and in any case is not less that 25 inches wide.

(3) All planks forming a gangway or run shall be so fixed and supported as to prevent unequal sagging.

(4) No gangway or run shall be used the slope of which exceeds 1 vertical to 1½ horizontal.

(5) Where the slope of a gangway or run renders additional foothold necessary, and in every case where the slope is more than 1 vertical to 4 horizontal, there shall be provided proper stepping laths which shall—

(*a*) be placed at suitable intervals, and

(*b*) be the full width of not more than 4 inches to facilitate the movement of barrows.

Guard-rails, toe-boards, hand-rails, etc., for gangways, runs and stairs

27.—(1) Stairs shall be provided throughout their length with handrails or other efficient means to prevent the fall of persons except for the time and to the extent necessary for the access of persons or the movement of materials. If necessary to prevent danger to any person the hand-rails shall be continued beyond the ends of the stairs.

(2) All gangways, runs and stairs from which a person is liable to fall a distance of more than 6 feet 6 inches shall be provided with—

(*a*) suitable guard-rails of adequate strength to a height of at least 3 feet above the gangway, run or stair;

(*b*) except in the case of stairs, toe-boards up to a sufficient height being in no case less than 8 inches and so placed as to prevent so far as possible the fall of persons, materials and tools. The space between any such toe-board and the lowest guard-rail above it shall not exceed 27 inches:

Provided that paragraph (2) of this Regulation shall not apply to a temporary gangway which is used only by erectors of structural steelwork or ironwork for the purpose of bolting-up, riveting or welding work of such short duration as to make the provision of a gangway with guard-rails and toe-boards unreasonable.

Platforms, gangways, etc., to be unobstructed and to afford safe foothold

28.—(1) Every platform, gangway, run or stair shall be kept free from any unnecessary obstruction, material or rubbish and from any projecting nails.

(2) If a platform, gangway, run or stair becomes slippery appropriate steps shall as soon as reasonably practicable be taken by way of sanding, cleaning or otherwise to remedy the defect.

Ladders and step-ladders

29.—(1) Every ladder and step-ladder shall be of good construction, sound material and adequate strength for the purpose for which it is used.

(2) Where a ladder is used as a means of communication or as a working place the ladder shall rise, or adequate handhold shall be provided, to a height of at least 3 feet 6 inches above the place of landing or the highest rung to be reached by the feet of any person working on the ladder as the case may be or if that is impracticable to the greatest practicable height:

Provided that paragraph (2) of this Regulation shall not apply to a crawling ladder.

(3) Ladders or step-ladders shall not stand on loose bricks or other loose packing, but shall have a level and firm footing.

(4) Every ladder shall so far as practicable be securely fixed so that it can move neither from its top nor from its bottom points of rest.

If it cannot be so securely fixed it shall where practicable be securely fixed at the base or if such fixing at the base is impracticable a person shall be stationed at the base of the ladder to prevent slipping.

Provided that this paragraph shall not apply to a ladder which is not more than 10 feet in length and which is not used as a means of communication, if the ladder is securely placed so as to prevent it from slipping or falling.

(5) Every ladder shall be—

(*a*) secured where necessary to prevent undue swaying or sagging;

(*b*) equally and properly supported on each upright.

(6) Every ladder or run of ladders rising a vertical distance of over 30 feet shall if practicable be provided with an intermediate landing place or places so that the vertical distance between any two successive landing places shall not exceed 30 feet. Every landing place shall be of adequate dimensions and, if a person is liable to fall thereform for a distance of more than 6 feet 6 inches, shall, except in so far as that is not reasonably practicable, be provided with sufficient and suitable guard-rails to a height of at least 3 feet above the landing place. Where a ladder passes through an opening in the floor of a landing place, the opening shall be as small as is reasonably practicable.

(7) No ladder shall be used which has—

(*a*) a missing or defective rung; or

(*b*) any rung which depends for its support solely on nails, spikes, or other similar fixing.

(8) No wooden ladder shall be used unless it is constructed with—

(*a*) uprights of adequate strength made of stright-grained wood free from defects and having the grain of the wood running lengthwise; and

(*b*) rungs made of straight-grained wood free from defects and mortised or securely notched into the uprights; and

(*c*) reinforcing metal ties if the tenons are not secured by wedges.

Openings in roofs, floors and walls; open joisting

30.—(1) Subject to paragraphs (5) and (6) of this Regulation every accessible opening in a roof or in the floor of a building, working platform, gangway, or run, through which any person is liable to fall a distance of more than 6 feet 6 inches, shall be provided with—

(*a*) a suitable guard-rail or guard-rails of adequate strength to a height of at least 3 feet above the edge of such opening, together with toe-boards up to a sufficient height, being in no case less than 8 inches, and so placed as to prevent so far as possible the fall of persons, materials, and tools through the opening; or

(*b*) a covering so constructed as to prevent the fall of persons, materials and tools through the opening.

Provided that in the case of an opening of a pit in the floor of a factory which is not ordinarily fenced, the requirements of this paragraph shall not apply by reason only that repair or maintenance work to which these Regulations apply is being done by persons normally engaged on such repair or maintenance work in the factory.

(2) Subject to paragraphs (5) and (6) of this Regulation where there is any accessible opening in a wall through which a person is liable to fall a distance of more than 6 feet 6 inches from any floor, platform, or working place less than 2 feet 3 inches below the bottom of the opening, the opening shall be provided with—

(*a*) a suitable guard-rail or guard-rails of adequate strength to a height of at least 3 feet above the floor, platform, or working place, and

(*b*) a toe-board or toe-boards not less than 8 inches high where necessary to prevent the fall of persons, materials, and tools, through the opening.

(3) Subject to paragraphs (5) and (6) of this Regulation when work is done on or immediately above open joisting through which a person is liable to fall a distance of more than 6 feet 6 inches, the joisting shall be securely covered over by temporary boards or other covering where and to the extent necessary to afford safe access to or foothold for the work, or other effective measures shall be taken to prevent persons from falling.

(4) In the case of an opening to which the foregoing requirements of this Regulation do not apply by reason that a person is not liable to fall through the opening to a distance of 6 feet 6 inches but from the edge of which tools or other articles or materials are liable to fall so as to endanger persons employed, suitable precautions by way of the erection of toe-boards, secure covering or otherwise shall be taken to prevent tools, articles and materials so falling.

(5) Guard-rails, toe-boards, and coverings required by paragraphs (1), (2), (3) or (4) of this Regulation may be removed or remain unerected—

(*a*) where and when this is or becomes necessary in order to proceed with any permanent filling in, covering, or enclosure of the opening or open joisting; or

(*b*) for the time and to the extent necessary for the access of persons or the movement of materials.

(6) Without prejudice to Regulation 24, paras, (1), (2), (3) and (4) of this Regulation shall not apply to an opening created in the course of demolition operations to which Part V of these Regulations applies, or to an opening created in the course of any other demolition operation, if in the course of such last mentioned demolition operation it is not left unattended, or unprotected by a suitable guard-rail or by a suitable cover where and when persons employed are liable to pass near or across the opening.

Roof work

31.—(1) Where work is done on the sloping surface of a roof and, taking into account the pitch, the nature of the surface, and the state of the weather, a person employed is likely to slip down or off the roof, then unless he has adequate hand hold or foothold or is not liable to fall a distance of more than 6 feet 6 inches from the edge of the roof, suitable precautions shall be taken to prevent his so falling.

(2) Extensive work on the sloping surface of any roof which has a pitch of over 34 degrees and from or down any part of which a person is liable to fall a vertical distance of more than 6 feet 6 inches, shall be done only by workmen who are suitable for such work, and when such work is done—

(*a*) there shall be provided sufficient and suitable crawling ladders or crawling boards which shall be secured as soon as practicable; and

(*b*) there shall be provided where practicable a suitable working platform, securely supported, and not less than 17 inches wide;

(*c*) when a person is employed on a roof where he is liable to slip down the slope and fall off the edge of the roof covering to a distance of more than 6 feet 6 inches, there shall be a parapet wall or railings of adequate strength or other protective arrangements to prevent him so falling;

(*d*) in the case of any part of the work for which it is impracticable to comply with sub-paragraphs (*a*) and (*c*) of this paragraph, a suitable safety belt of suitable and sound material and in good condition, with a rope of adequate length and strength enabling the wearer to attach himself to a fixed and suitable structure, shall be supplied to each workman who elects to use it and where the wearer cannot so attach himself a second person shall attach or hold the rope in a secure manner.

(3) Where work is being done on or near roofs or ceilings covered with fragile materials through which a person is liable to fall a distance of more than 10 feet—

(*a*) where workmen have to pass over a work above such fragile materials, suitable and sufficient ladders, duck ladders or crawling boards, which shall be securely supported, shall be provided and used;

(*b*) prominent notices stating that the coverings are fragile shall be affixed at the approaches thereto.

Provided that sub-paragraph (*b*) shall not apply as respect glass coverings.

(4) Where persons are employed in a position below the edge of a sloping roof and where they are in a position of being endangered by work done on the roof, suitable precuations shall be taken to prevent tools, or materials falling from such roofs or from the edge thereof so as to endanger such persons employed.

Scaffolds not to be overloaded

32. Scaffolds shall not be over-loaded and materials shall not be kept upon them unless needed for work within a reasonable time.

Avoidance of shock on scaffolds

33. When any material is transferred on or to a scaffold it shall be moved or deposited without imposing any violent shock.

PART III.—RAISING AND LOWERING

A. LIFTING APPLIANCES

Construction, maintenance and inspection

34.—(1) Every lifting appliance and every part thereof including all working gear and all plant or gear used for anchoring or fixing such appliances shall—

(*a*) be of good mechanical construction, sound material, adequate strength and substance and free from patent defect;

(*b*) be properly maintained;

(*c*) as far as the construction permits be inspected at least once in every week by the driver, if competent for the purpose, or other competent person. A report of the results of every such inspection in the prescribed form and including the prescribed particulars and signed by the person making the inspection shall be entered in or attached to the prescribed register forthwith.

(2) In the case of a site where the employer for whom the inspection was carried out has reasonable grounds for believing that the operations will be completed in a period of less than six weeks, the provision in this Regulation requiring that a report shall be made and signed, in so far as it relates to lifting appliances not worked by mechanical power and all plant or gear used for anchoring or fixing such appliances, shall be deemed to have been satisfied if the person in charge of the operations carried on by that employer at such site has himself carried out the inspection and is a person competent so to do and if, within one week of the date of the inspection, he informs his employer in writing that the lifting appliance and plant or gear were inspected by him and that he found them in good order, or observed certain defects as the case may be, and the date of such inspection and the results thereof together with the name of the person making the inpsection are entered in the prescribed register.

Support, anchoring, fixing and erecting

35.—(1) Every lifting appliance shall be adequately and securely supported and every part of a stage, framework or other structure and every mast, beam, pole or other article of plant supporting any part of a lifting appliance shall be of good construction, sound material and adequate strength having regard to the nature of the lifting appliance, its lifting and reaching capacity, and the circumstances of its use.

(2) Every part of the framework of every crab or winch, including the bearers, shall be of metal, provided that in the case of a crab or winch not driven by mechanical power this requirement shall not as respects bearers come into force until twelve months after the commencement of these Regulations.

(3) The anchoring or fixing arrangements of every lifting appliance shall be adequate and secure.

(4) Every temporary attachment or connection of a rope, chain or other plant or gear used in the erection or dismantling of any lifting appliance shall be adequate and secure.

Precautions where lifting appliance has travelling or slewing motion

36. On every stage, gantry or other place where a lifting appliance having a travelling or slewing motion is used, an unobstructed passageway not less than 2 feet wide shall be maintained between any part of the appliance liable so to move and any guard-rails, fencing or other nearby fixture:

Provided that if at any time it is impracticable to maintain such a passageway at any place or point all reasonable steps shall be taken to prevent the access of any person to such place or point at such time.

Platforms for crane drivers and signallers

37. Every platform for the person or persons driving or operating a crane, or for any signaller, shall be—

(*a*) of sufficient area for the persons employed thereon;

(*b*) close planked or plated;

(*c*) provided with safe means of access;

and Regulation 24 (which relates to guard-rails and toe-boards) shall apply to such platform as if it were a working platform.

Cabins for drivers

38.—(1) The driver of every power-driven lifting appliance shall be provided with a suitable cabin which shall (*a*) afford him adequate protection from the weather and (*b*) be so constructed as to afford ready access to such parts of the lifting appliance as are within the cabin and need periodic inspection or maintenance, so, however, that no cabin shall be provided which prevents the driver from having such clear and unrestricted view as is necessary for safe use of the appliance.

(2) Where reasonably practicable the cabin shall, before such lifting appliance is put into general use, be completely erected, or other adequate provision shall be made for the protection of the driver from the weather.

(3) Where reasonably practicable the cabin shall when in use during cold weather be adequately heated by suitable means.

(4) Paragraphs (1), (2) and (3) of this Regulation shall not apply in cases where the driver is indoors or otherwise adequately protected from the weather, or to a hoist other than a hoist operated only from one position alongside the winch, or to lifting appliances mounted on wheels and having a maximum safe working load of one ton or less or to any machine incorporating a lifting appliance where the primary purpose of that machine is not that of a lifting appliance.

Drums and pulleys

39. Every drum or pulley round which the chain or wire rope of any lifting appliance is carried shall be of suitable diameter and construction for the chain or rope used. Every chain or rope which terminates at the winding drum of a lifting appliance shall be properly secured thereto and at least two turns of such chain or rope shall remain on the drum in every operating position of the appliance.

Brakes, controls, safety devices, etc.

40.—(1) Every crane, crab and winch shall be provided with an efficient brake or brakes or other safety device which will prevent the fall of the load when suspended, and by which the load can be effectively controlled whilst being lowered.

(2) On every lifting appliance every lever, handle or wheel provided for controlling the operation of any part of the appliance shall, where practicable, be provided with a suitable locking device to prevent accidental movement or displacement of the lever, handle or wheel unless it is so placed or constructed as to prevent such accidental movement or displacement or unless the appliance is so constructed that such accidental movement or displacement will not affect the appliance in a manner liable to cause danger. This requirement shall not apply until the expiration of six months from the date of commencement of these Regulations.

(3) Every lever, handle or wheel provided for controlling the operation of any part of a lifting appliance shall have upon or adjacent to it clear markings to indicate its purpose and mode of operation provided that this requirement shall not apply to rotating handles for raising or lowering the load in the case of a winch or non-derricking crane not operated by mechanical power.

Safe means of access

41. Where any person engaged on the examination, repair or lubrication of any lifting appliance is liable to fall a distance of more than 6 feet 6 inches there shall, so far as is reasonably practicable, be provided and maintained safe means of access to the place at which the person has to work, with, where necessary, adequate handholds and footholds.

Poles or beams supporting pulley blocks or gin wheels

42. No pulley block or gin wheel suspended from or supported by a pole or beam shall be used for raising or lowering materials unless it is effectively secured to the pole or beam and the pole or beam—

(*a*) is of adequate strength for the purpose for which it is being used; and

(*b*) is adequately secured at at least two points so as to support the load with safety and so as to prevent the pole or beam from moving into contact with any part of a scaffold; and

(*c*) is not supported on a part of a scaffold which also serves as a ledger or putlog; and

(*d*) if secured only to a scaffold, is secured to at least two standards or extension poles of that scaffold.

Stability of mobile lifting appliances

43. No mobile lifting appliance shall be used on a soft or uneven surface or on a slope in circumstances in which the stability of the appliance is likely to be affected unless adequate precautions are taken to ensure its stability.

Stability of fixed cranes and guards for travelling jib cranes on rails

44.—(1) No fixed crane shall be used unless it is securely anchored or adequately weighted by suitable ballast properly placed on the crane structure so as to ensure stability.

(2) Where the stability of a crane is secured by means of removable weights a diagram or notice indicating the position and amounts of such weights shall be affixed on the crane where it can readily be seen.

(3) Every travelling jib crane on rails shall be provided with guards to remove any loose material from the track.

Rails for travelling cranes

45. All rails on which a travelling crane moves shall—

(*a*) be of adequate section and have an even running surface;

(*b*) be jointed by fish plates or double chairs;

(*c*) be securely fastened to sleepers or bearers;

(*d*) be properly laid;

(*e*) be maintained in good condition;

(*f*) be provided with stops or buffers at the ends of the track;

Provided that requirements (*b*) and (*c*) of this Regulation shall not apply to an overhead crane on bridge rails or to any crane if other adequate steps are taken to ensure the proper junction of the rails, and to prevent any material variation in their gauge.

Cranes with derricking jibs

46. On every crane having a derricking jib there shall be provided and maintained an effective interlocking arrangement of sound construction between the derricking clutch and the pawl sustaining the derricking drum, except where :—

(*a*) the hoisting drum and the derricking drum are independently driven; or

(*b*) the mechanism driving the derricking drum is self-locking.

User of cranes

47. A crane shall not be used—

(*a*) otherwise than for direct raising or lowering of a load unless the stability of the crane is not thereby endangered;

(*b*) in the case of a crane with a derricking jib, to move a load at a radius exceeding the maximum radius specified in the certificate required by Regulation 52, or where no such certificate is yet required, the maximum radius marked on the crane in accordance with paragraph (3) of Regulation 53.

Uses of cranes with timber structural member prohibited

48. No crane which has any timber structural member shall be used.

Erection of cranes under supervision

49. A crane shall not be erected except under the supervision of a competent person.

Competent persons to operate lifting appliances or give signals

50.—(1) A lifting appliance shall not be operated except by a person trained and competent to operate that appliance except that it shall be permissible for such appliance to be operated by a person who is under the direct supervision of a qualified person for the purpose of training.

(2) No person under 18 years of age shall be employed to operate any lifting appliance driven by mechanical power or to give signals to the operator of any such appliance.

(3) Subject to paragraph (4) of this Regulation, if the person operating a lifting appliance has not a clear and unrestricted view of the load or, where there is no load, of the point of attachment for a load, and of its vicinity, throughout the operation, except at any places where such view is not necessary for safe working, there shall be appointed and suitably stationed one competent person to give necessary signals to the operator, but if one signaller is insufficient for the purpose such additional competent signallers as may be necessary shall be appointed and suitably stationed:

Provided that where and in so far as it is impracticable to comply with the foregoing requirements of paragraph (3) of this Regulation effective measures shall be taken to enable the driver or operator of the lifting appliance to ascertain the position of the load, or point of attachment for a load, when it is in the vicinity of a loading or unloading point or of any other place at which danger is reasonably to be anticipated.

(4) The provision of paragraph (3) of this Regulation shall not apply—

(*a*) in the case of a hoist or of an aerial cableway;

(*b*) in a case other than that of a hoist as respects places where the appliance can raise or lower the load (or point of attachment for a load) vertically only, without any horizontal or slewing motion, if for safe working the driver or operator of the appliance needs information related to the movement, stopping of position of the load, or point of attachment for a load, when it is at or in the immediate vicinity of certain points only, and effective arrangment are made by means of a signalling system, position indicators or otherwise, for providing the driver or operator with any such information necessary for safe working.

(5) There shall be efficient signalling arrangement between the driver or operator and persons employed at a loading or unloading point of an aerial cableway.

Signals

51.—(1) Every signal given for the movement or stopping of a lifting appliance shall be distinctive in character and such that the person to whom it is given is able to hear or see it easily.

(2) Devices or apparatus used for giving sound, colour or light signals for the purposes aforesaid shall be efficiently and properly maintained, and signal wires shall be adequately protected from accidental interference.

Testing and examination of lifting appliances

52.—(1) (*a*) No crane, crab or winch shall be used unless it has been tested and thoroughly examined by a competent person within the previous four years and no pulley block, gin wheel or sheer legs shall be used in the raising or lowering of any load weighing one ton or more unless it has been tested and thoroughly examined by a competent person;

(*b*) No crane, crab or winch shall be used after any substantial alteration or repair until it has been tested and thoroughly examined by a competent person and no pulley block, gin wheel or sheer legs shall, after any substantial alteration or repair, be used in the raising or lowering of any load weighing one ton or more until it has been tested and examined by a competent person;

(*c*) No lifting appliance shall be used unless it has been thoroughly examined by a competent person within the previous fourteen months and since it has undergone any substantial alteration or repair :

Provided that sub-paragraph (*a*) shall not apply within a period of two years after the date of commencement of these Regulations, except in the case of Scotch Derrick, Guy Derrick, Tower Derrick and Travelling Jib cranes.

Provided also that paragraph (1) of this Regulation shall not apply to a hoist.

(2) No crane, crab, winch, pulley block or gin wheel shall be used unless there has been obtained in such form as may be prescribed a certificate of any test and examination required by sub-paragraphs (*a*) or (*b*) of paragraph (1) of this Regulation signed by the person making or responsible for the carrying out of the test and examination and specifying the safe working load or safe working loads and in the case of a crane with a derricking jib the safe working loads at various radii of the jib including the maximum radius at which the jib may be worked.

(3) A report of the results of any examination required by paragraph (1) of this Regulation in such form and including such particulars as may be prescribed and signed by the person making or responsible for the carrying out of the examination shall within 14 days be entered in or attached to the prescribed register; provided that this requirement shall not apply to an examination of which a certificate has been obtained in accordance with paragraph (2) of this Regulation.

Marking of safe working loads

53.—(1) The safe working load or safe working loads and a means of identification shall be plainly marked—

(*a*) upon every crane, crab, or winch;

(*b*) upon every pulley block, gin wheel, sheer legs or derrick pole or mast used in the raising or lowering of any load weighing 1 ton or more.

(2) In the case of a crane which is on occasion dismantled or partially dismantled, any structural member which is separated from the crane in dismantling shall be clearly marked so as to indicate the crane of which it is a part.

(3) Every crane fitted with a derricking jib shall—

(*a*) have plainly marked upon it the safe working loads at various radii of the jib and the maximum radius at which the jib may be worked;

(*b*) be fitted with an accurate indicator, clearly visible to the driver, showing the radius of the jib at any time and the safe working load corresponding to that radius.

Indication of safe working load of jib cranes

54. Subject as hereinafter in this Regulation provided, no jib crane having either a fixed or a derricking jib shall be used unless it is fitted with an approved type of automatic indicator which—

(*a*) indicates clearly to the driver or person operating the crane when the load being carried approaches the safe working load of the crane for the radius of the jib at which the load is being carried;

(*b*) gives an efficient sound signal when the load being carried is in excess of the safe working load of the crane at that radius.

Provided that if a table showing the safe working loads at various radii of the jib is kept attached to the crane the foregoing requirements shall not apply to—

(i) any Guy Derrick crane, being a crane of which the mast is held upright solely by means of ropes with the necessary fittings and tightening screws;

(ii) any hand crane which is being used solely for erecting or dismantling another crane;

(iii) any crane having a maximum safe working load of 1 ton or less.

Provided also that in the case of a crane having a maximum safe working load of not more than 30 hundredweight the foregoing requirements shall not apply until the expiration of one year from the date of the commencement of these Regulations.

Load not to exceed safe working load

55. A crane, crab, winch, pulley block, gin wheel, sheer legs, or derrick pole or mast or any part of such appliance shall not be loaded beyond the safe working load, provided that for the purpose of making tests of any such appliance the safe working load may be exceeded by such amount as a competent person appointed to carry out the tests may authorise.

Precautions on raising or lowering loads

56.—(1) Where there is lifted on a lifting appliance a load which is equal to or slightly less than the relevant safe working load and which is not already sustained wholly by the appliance, the lifting shall be halted after the load has been raised a short distance and before the operation is proceeded with.

(2) Where more than one lifting appliance is required to lift or lower one load—

(*a*) the machinery, plant and other appliances used shall be so arranged and fixed that no such lifting appliance shall at any time be loaded beyond its safe working load or be rendered unstable in the raising or lowering of the load;

(*b*) a competent person shall be specially appointed to supervise the operation.

Scotch, Guy or Tower Derrick cranes

57.—(1) The requirements of paragraphs (2) to (9) of this Regulation shall, except as otherwise specified, apply to all Scotch Derrick, Guy Derrick or Tower Derrick cranes and to such cranes only.

(2) (*a*) No crane manufactured after 30th September, 1931, shall be used unless it conforms to the standards of strength, stability and safety specified in the British Standard Specification No. 327 of 1930 for Derrick Cranes as amended by any amendments thereof made and published by the British Standards Institution not later than six months prior to the manufacture of the crane, or specified in an alternative specification approved for the purpose of these Regulations, and a certificate that it so conforms has been obtained from the makers of the crane.

(*b*) No crane manufactured before the 1st October, 1931, shall be used unless it has been brought up to or brought as near as is reasonably practicable to the standards of strength, stability and safety specified in British Standard Specification No. 327 of

1930 for Derrick Cranes, and there has since been obtained in the prescribed form a certificate from a competent person that he has tested and examined the crane and specifying the safe working load or safe working loads.

(*c*) No crane which, after 30th September, 1931, is or has been converted from a hand crane to a power crane shall be used unless, since such conversion, it has been brought up to or brought as near as is reasonably practicable to the standards of strength, stability and safety specified in British Standard Specification No. 327 of 1930 for power driven Derrick Cranes or specified in an alternative specification approved for the purposes of these Regulations and there has since such conversion been obtained in the prescribed form a certificate from a competent person that he has tested and examined the crane and specifying the safe working load or safe working loads.

(3) The whole of the appliances for the anchorage of a crane shall be examined by a competent person on each occasion before the crane is erected.

(4) Every crane shall after each erection on a building site and before use be tested in situ for anchorage, by a competent person, by the imposition on each anchorage of the maximum uplift or pull exerted either—

(*a*) by a load of 25 per cent. above the maximum load to be lifted by the crane as erected; or

(*b*) by a less load arranged to exert an equivalent pull on the anchorage.

The prescribed particulars of such tests and their results shall forthwith be entered in or attached to the prescribed register.

(5) If the person making tests under paragraph (4) of this Regulation considers that the maximum load which may safely be lifted by that crane as anchored is less than the safe working load of the crane as defined in Regulation 3 he shall specify that maximum among the said particulars and a loading diagram appropriate to the crane anchorage and indicating a modified safe working load or loads shall be affixed in a position where it can readily be seen by the crane driver. Such modified safe working load or loads shall be deemed for the purpose of these Regulations to be the safe working load or loads of the crane as anchored.

(6) The jib of a Scotch Derrick crane shall not be erected between the back stays of the crane.

(7) No load which lies in the angle between the back stays of a Scotch Derrick crane shall be moved by that crane.

(8) Appropriate measures shall be taken to prevent the foot of the king post of any Scotch Derrick or Tower Derrick crane from being lifted out of its socket or support whilst in use.

(9) Where the guys of a Guy Derrick crane cannot be fixed at approximately equal inclinations to the mast and so that the angles between adjacent pairs of guys are approximately equal such other measures shall be taken as will ensure the stability of the crane.

B. CHAINS, ROPES AND LIFTING GEAR

Construction, testing, examination and safe working loads of chains, ropes and lifting gear

58.—(1) No chain, rope or lifting gear shall be used in raising or lowering or as a means of suspension unless—

(*a*) it is of good construction, sound material, adequate strength, suitable quality, and free from patent defect;

(*b*) it has been tested and examined by a competent person and there has been obtained in such form as may be prescribed a certificate of such test and examination specifying the safe working load and signed by the person making or responsible for the carrying out of the test and examination; and

(*c*) it is marked in plain legible figures and letters with the safe working load and means of identification.

Provided that sub-paragraph (*b*) of this paragraph shall not apply

(i) to a fibre rope or fibre sling; or

(ii) to a wire rope used before the date of commencement of these Regulations.

Provided further that a rope or rope sling need not be marked with the safe working load if its safe working load is entered in the register kept in pursuance of Regulation 64 and the rope or sling is so marked as to enable its safe working load to be ascertained from the register or if, in the case of a rope or rope sling to which sub-paragraph (*b*) of this paragraph does not apply, its safe working load can be ascertained from a table of safe working loads posted in a prominent position on the site of the operations; and in the case of a rope or rope sling which is not required to have been tested and which is not marked with the safe working load, the safe working load entered in the register or shown by the table, as the case may be, shall be deemed for the purpose of these Regulations to be the safe working load of the rope or rope sling.

(2) No wire rope shall be used in raising or lowering or as a means of suspension if in any length of ten diameters the total number of visible broken wires exceeds five per cent. of the total number of wires in the rope.

(3) No chain, rope or lifting gear shall be loaded beyond its safe working load except for the purpose of making tests and then only to such extent as a competent person appointed to carry out the tests may authorise.

Testing of chains, rings, etc., altered or repaired by welding

59. No chain, ring, link, hook, shackle, swivel or eyebolt which has been lengthened, altered or repaired by welding shall be used in raising or lowering or as a means of suspension unless since such lengthening, alteration or repair it has been tested and examined by a competent person and there has been obtained in the prescribed form a certificate of such test and examination signed by him or by the person responsible for the carrying out of the test and examination and specifying the safe working load.

Hooks

60. Every hook used for raising or lowering or as a means of suspension shall either—

(*a*) be provided with an efficient device to prevent the displacement of the sling or load from the hook; or

(*b*) be of such shape as to reduce as far as possible the risk of such displacement.

Slings

61.—(1) Every chain sling or rope sling used for raising or lowering on a lifting appliance shall be securely attached to the appliance, and the method of attachment shall not be a method likely to result in damage to any part of the sling or to any lifting gear supporting it.

(2) No double or multiple sling shall be used for raising or lowering if—

(*a*) the upper ends of the sling legs are not connected by means of a shackle, ring or link of adequate strength; or

(*b*) the safe working load of any sling leg is exceeded as a result of the angle between the sling legs.

Edges of load not to come into contact with sling, etc.

62. Adequate steps shall be taken by the use of suitable packing or otherwise to prevent the edges of the load from coming into contact with any sling, rope or chain, so as to cause danger.

Knotted chains, etc.

63.—(1) A load shall not be raised, lowered or suspended on a chain or wire rope which has a knot tied in any part of the chain or rope under direct tension.

(2) No chain which is shortened or joined to another chain by means of bolts and nuts shall be used for raising, lowering or suspending any load.

Examination of chains, ropes and lifting gear

64. No chain, rope or lifting gear shall be used for raising or lowering or as a means of suspension unless it has been thoroughly examined by a competent person at least once within the previous six months, so however that chains, ropes and lifting gear not in regular use need only be so examined when necessary. A register shall be kept showing the prescribed particulars with respect to each such examination.

Annealing of chains and lifting gear

65. A chain or lifting gear other than a rope sling or lifting gear of a class or description specified in the First Schedule to these Regulations, or exempted by certificate of the Chief Inspector upon the ground that it is made of such material or so constructed that it cannot be subjected to heat treatment without risk of damage, shall not be used in raising or lowering or as a means of suspension unless—

(*a*) it has been effectively annealed or subjected to some approved form of heat treatment under the supervision of a competent person within the previous fourteen months or, in the case of chains or slings of half-inch bar or smaller material, within the previous six months, so however that chains or lifting gear not in regular use or used solely on lifting appliances worked by hand need be annealed or subjected to approved heat treatment only when necessary; and

(*b*) the prescribed particulars of annealing or approved heat treatment have been entered in or attached to the prescribed register.

C. SPECIAL PROVISIONS AS TO HOISTS

Safety of hoistways, platforms and cages

66.—(1) The hoistway of every hoist shall at all points at which access to the hoistway is provided or at which persons are liable to be struck by any moving part of the hoist be efficiently protected by a substantial enclosure, and the enclosure shall where access to the hoist is needed be fitted with gates. Such enclosure and gates shall extend to a height of at least six feet six inches except where a lesser height is sufficient to prevent any person falling down the hoistway and there is not risk of any person coming into contact with any moving part of the hoist, but in no case shall be less than three feet. Gates so fitted shall be kept closed except at a landing place where the platform or cage is at rest and it is for the time being necessary for the gate to be open for the purpose of loading or unloading goods, plant or materials or to allow persons to enter or leave the cage; and without prejudice to the obligation of employers under these Regulations, it shall be the duty of every person, immediately after using any gateway, to see that the gate is closed unless it is for the time being necessary for the gate to be open for any of the purposes aforesaid.

(2) In connection with every hoist there shall be provided and maintained efficient devices which will support the platform or cage together with its safe working load in the event of failure of the hoist rope or ropes or any part of the hoisting gear.

(3) In connection with every hoist there shall be provided and maintained efficient automatic devices which will ensure that the platform or cage does not over-run the highest point to which it is for the time being constructed to travel.

(4) Except in the case of a hoist used for carrying persons the requirements of paragraphs (2) and (3) of this Regulation shall not apply until one year or, where the height of travel of the cage of platform does not exceed thirty feet, two years after the commencement of these Regulations.

Operation of hoists

67.—(1) The construction and the installation arrangements of every hoist shall at any one time be such that it can be operated only from the cage or only from one other position and a hoist shall not be operated from the cage unless the requirements of Regulation 69 are complied with.

(2) If the person operating a hoist has not a clear and unrestricted view of the platform or cage throughout its travel, except at points where such a view is not necessary for safe working, then effective arrangements shall be made for signals to be give to him from each landing place at which the hoist is used and to enable him to stop the platform or cage at the appropriate level.

(3) When a hoist is not operated from the cage there shall be a readily legible notice on the platform or cage stating that the carriage of persons is prohibited.

Winches

68. Where a hoist is operated by means of a winch, the winch shall be so constructed that the brake is applied when the control lever, handle or switch is not held in the operating position, and the winch shall not be a winch fitted with a pawl and ratchet gear on which the pawl has to be disengaged before the platform or cage can be lowered.

Hoists carrying persons

69.—(1) No hoist shall be used for carrying persons unless it is provided with a cage, which is—

(*a*) so constructed as to prevent, when the cage gate or gates are shut, any person carried from falling out or from being trapped between any part of the cage and any fixed structure or other moving part of the hoist or from being struck by articles or materials falling down the hoistway; and

(*b*) fitted on each side from which access is provided to a landing place with a gate with efficient inter-locking or other devices to secure that the gate cannot be opened except when the cage is at a landing place and that the cage cannot be moved away from any such place until the gate is closed.

(2) Every gate in the hoistway enclosure of a hoist used for carrying persons shall, if or so far as reasonably practicable, be fitted with efficient interlocking or other devices to secure that the gate cannot be opened except when the cage is at the landing place, and that the cage cannot be moved away from the landing place until the gate is closed.

(3) In connection with every hoist used for carrying persons there shall be provided suitable efficient automatic devices which will ensure that the cage comes to rest at a point above the lowest point to which the cage can travel.

(4) Every hoist in which any person is being carried shall be operated from the cage of the hoist only.

Safe working load of hoists

70. The safe working load shall be plainly marked on every hoist platform or cage and no load greater than that load shall be carried, provided that for the purpose of carrying out a test the safe working load may be exceeded by such amount as a competent person appointed to carry out the test may authorise. In the case of a hoist used for carrying persons the maximum number of persons to be carried at any one time shall also be so marked, and a greater number of persons shall not be so carried.

Tests and examination of hoists

71. No hoist shall be used—

(*a*) unless, in the case of a hoist manufactured or substantially altered or substantially repaired after the date of commencement of these Regulations, it has, since such manufacture, alteration or repair as the case may be, been tested

and thoroughly examined by a competent person, and there has been obtained, in such form as may be prescribed, a certificate of such test and examination signed by the person making or responsible for the carrying out of the test and examination and specifying the safe working load of the hoist and in the case of a hoist used for carrying persons the maximum number of persons to be carried at one time;

(*b*) unless, in the case of use for carrying persons, it has, since it was last erected or the height of travel of the cage was last altered, whichever is the later, been tested and thoroughly examined by a competent person and a report of the results of such test and examination, in such form and including such particulars as may be prescribed, and signed by the person making or responsible for the carrying out of the test and examination, has been entered in or attached to the prescribed register; and

(*c*) unless it has been thoroughly examined by a competent person at least once within the previous six months.

A report of the results of any examination required by paragraph (*c*) of this Regulation in such form and including such particulars as may be prescribed and signed by the person making or responsible for the examination shall within 14 days be entered in or attached to the prescribed register.

Hoists forming part of permanent equipment of a building

72.—(1) Regulations 34, 39 and 66 to 71 inclusive shall not apply to a passenger or goods hoist forming part of the permanent equipment of a building but no such hoist shall be used for the purposes of any operations to which these Regulations apply unless the following conditions are complied with—

(*a*) the hoist shall not be so used for carrying persons unless a maximum number of persons to be carried at any one time has been specified by the maker or by an insurer of the hoist or by a competent firm of lift engineers carrying out periodic examinations of the hoist, and a greater number is not being carried;

(*b*) the hoist shall not be so used for carrying materials, tools or other articles, other than light articles readily carried by a person who is riding in the hoist, unless a safe working load for the hoist has been specified by the maker or an insurer or firm as aforesaid and that safe working load is not being exceeded;

(*c*) on any occasion when the hoist has been used for raising or lowering for the purposes of such operations the hoistway gate at a landing place shall not be left open except where it is immediately necessary for it to be open to afford access to the hoist for some other purpose.

(2) In the case of a hoist manufactured before the date of commencement of these Regulations, if it is not reasonably practicable to comply fully with any requirement of Regulations 66 (2), 66 (3), 68, 69 (1), 69 (2) or 69 (3), it shall be sufficient if the hoist has been brought as near as is reasonably practicable into conformity with that requirement and a certificate that this has been done has been obtained from a competent person.

D. GENERAL

Carrying of persons by crane

73. No person shall be raised, lowered or carried by a crane except on the driver's platform or as permitted by Regulation 18.

Secureness of loads

74.—(1) Every part of a load shall be securely suspended or supported whilst being raised or lowered and shall be adequately secured to prevent danger from slipping or displacement.

(2) Where by reason of the nature or position of the operation a load is liable, whilst being moved on a lifting appliance or lifting gear, to come into contact with any object so that the object may become displaced, special measures shall be adopted to prevent the danger so far as reasonably practicable.

(3) Every receptacle used for raising or lowering stone, bricks, tiles, slates or other objects shall be so enclosed, constructed or designed as to prevent the accidental fall of such objects :

Provided that this requirement shall not apply to a grab, shovel or other similar excavating receptacle if effective steps are taken to prevent any person being endangered by a fall of objects therefrom.

(4)—(*a*) Goods or loose material shall not be placed directly on the platform of a hoist unless such platform is enclosed or other effective precautions are taken where necessary to prevent the fall of any such goods or material.

(*b*) No truck or wheelbarrow shall be carried on a hoist platform unless it is efficiently scotched or secured on the platform.

(*c*) No loaded truck or wheelbarrow shall be carried on the open platform of a hoist unless the truck or wheelbarrow is so loaded that no part of the load is liable to fall off.

(5) The wheel of a barrow shall not be used as a means of suspension for raising or lowering the barrow unless efficient steps are taken to prevent the axle from slipping out of the bearings.

(6) No load shall be left suspended from a lifting appliance unless a competent person is actually in charge of the appliance.

PART IV.—EXCAVATIONS

Safety of excavations

75. An adequate supply of timber of suitable quality or other suitable material shall where necessary be provided and used to prevent, so far as is reasonably practicable and as early as is reasonably practicable in the course of the work, danger to any person employed from a fall or dislodgment of earth, rock or other material forming the side of or adjacent to any excavation or earthwork. Without prejudice to the carrying out of any other examination found necessary to ensure compliance with this Regulation every part of an excavation or earthwork, not being a part to which the proviso (i) below applies, shall be specially examined by a competent person at least once in every period of seven days for the purpose of assisting to ensure compliance with this Regulation and in particular to see that timber and other supports are adequate and in good condition; and a report of the results of every such examination shall be entered forthwith in the prescribed register. Provided that—

(i) this Regulation shall not apply where, having regard to the nature and slope of the side of the excavation or earthwork and other circumstances, no fall or dislodgment of earth or other material so as to bury or trap a person employed, or so as to strike a person employed from a height of more than four feet, is liable to occur;

(ii) this Regulation shall not apply in relation to a person actually engaged in timbering or other work (including an examination as aforesaid) which is being carried out for the purpose of compliance with this Regulation, if appropriate precautions are taken to ensure his safety as far as circumstances permit;

(iii) the foregoing requirements as to a special weekly examination and report thereon shall not apply until the work has been in progress for a period of at least seven working days (whether continuous or not);

(iv) in the case of a site where the employer for whom a special examination as aforesaid was carried out has reasonable grounds for believing that the operations will be completed in a period of less than six weeks, the provision in this Regu-

lation requiring a report of the examination to be entered in the register shall be deemed to have been satisfied if the person in charge of the operations carried on by that employer at such site has himself carried out the examination and is a person competent so to do and if within one week of the date of the examination he informs his employer in writing of the results of such examination, and the date of such examination and the results thereof together with the name of the person making the examination are entered in the prescribed register.

Excavations likely to reduce security of a structure

76. No excavation or earthwork which is likely to reduce so as to endanger any person employed the security or stability of any part of any structure, whether temporary or permanent, shall be commenced or continued unless adequate steps are taken before and during the progress of the work to prevent danger to any person employed from collapse of the structure or the fall of any part thereof.

Fencing of excavations, etc.

77. Every accessible part of an excavation, pit or opening in the ground into or down the side of which a person employed is liable to fall a vertical distance of more than 6 feet 6 inches shall be provided with a suitable barrier to a height of at least 2 feet and as close as is reasonably practicable to the edge:

Provided that the foregoing requirement shall not apply to any part of an excavation, pit or opening while (and to the extent to which) the absence of such barrier is necessary for the access of persons or for the movement of plant or materials or while (and to the extent to which) it has not yet been practicable to erect such barrier since the formation of that part of the excavation, pit or opening.

Safeguarding edges of excavations, etc.

78.—(1) Material shall not be placed or stacked near the edge of any excavation, pit or opening in the ground so as to endanger persons employed below.

(2) No load shall be placed or moved near the edge of any excavation where it is likely to cause a collapse of the side of the excavation and thereby endanger any person.

PART V.—DEMOLITION

Demolition of buildings

79.—(1) This Regulation shall apply to the demolition of any building or substantial part of a building.

(2) The demolition and operations incidental thereto shall be specifically placed under the supervision of a competent person experienced in demolition operations and appointed for the purpose whose name shall be posted up in a prominent position on the site of the operations, so however that where two or more contractors take part in the operations each such contractor shall appoint a competent person as aforesaid and either the same person shall be jointly appointed by every such contractor or each such contractor shall make arrangements to ensure that no operation is undertaken by his workmen except after consultation between all the persons so appointed as to the method by which and the time at which the operation is to be carried out.

(3) Before demolition is commenced and also during the progress of the work—

(*a*) no electric cable or apparatus which is liable to be a source of danger, other than a cable or apparatus used for the operation, shall remain electrically charged;

(*b*) all praticable steps shall be taken to prevent danger to persons employed—

(i) from risk of fire or explosion through leakage or accumulation of gas or vapour, and

(ii) from risk of flooding from water mains, sewers or culverts.

(4) No floor, roof or other part of the building shall be so overloaded with debris or materials as to render it unsafe.

(5) The following operations shall be carried out only (i) under the immediate supervision of a competent foreman or chargehand with adequate experience of the particular kind of work, or (ii) by workmen experienced in the kind of work and under the direction of a competent foreman or chargehand as aforesaid :—

(*a*) the actual demolition of the framework of a building or of any floor, wall, roof, staircase or chimney, except where there is no risk of a collapse of any part of a building in the course or as a result of the said demolition, so as to endanger any person employed, other than a risk which could not reasonably have been foreseen;

(*b*) the actual demolition of any part of a building where there is a special risk of a collapse, whether of that or of any other part of a building, in the course or as a result of the said demolition, so as to endanger any person employed;

(*c*) the cutting of reinforced concrete, steelwork or ironwork forming part of the structure of a building;

and before any steelwork or ironwork is cut or released, precautions shall be taken, so far as is practicable, to avoid danger from any sudden twist, spring or collapse.

(6) All practicable precautions shall be taken to avoid danger from collapse of the structure when any part of the framing is removed from a framed or partly framed building.

(7) Before demolition is commenced and also during the progress of the work precautions shall, where necessary, be taken by adequate shoring or otherwise to prevent, as far as practicable, the accidental collapse of any part of the building or of any adjoining building the collapse of which may endanger any person employed :

Provided that this requirement shall not apply in relation to any person actually engaged in erecting or placing shoring or other safeguards for the purpose of compliance with this Regulation if appropriate precautions are taken to ensure his safety as far as circumstances permit.

PART VI.—HEALTH AND WELFARE

First aid, ambulances and ambulance rooms

80.—(1) With a view to making adequate provision for the prompt first-aid treatment of all injuries likely to be sustained by persons employed during the course of operations to which these Regulations apply, the following requirements shall be observed.

(2) (*a*) In the case of a site where more than 10 persons are employed in operations to which these Regulations apply, a sufficient number of suitable first-aid boxes or cases shall be available at or in the immediate vicinity of the site in a readily accessible position or positions while work is going on;

(*b*) in the case of a site where more than 100 persons are employed in operations to which these Regulations apply, there shall be provided and available at or in the immediate vicinity of the site a properly constructed ambulance with a suitable stretcher or stretchers :

Provided that sub-paragraph (*b*) shall not apply if specific arrangements have been made for obtaining an ambulance and stretcher promptly, when required, from a hospital or other place to which telephonic communication from the site, or from a place in the immediate vicinity of the site, is readily available.

(3) Every first-aid box or case provided for the purpose of this Regulation shall :

(*a*) contain at least such equipment and materials as may be prescribed;

(*b*) be distinctly marked "FIRST AID";

(*c*) be placed under the charge of a responsible person who in the case of a site where more than 25 persons are employed shall be capable of giving first-aid treatment, who while in charge of the box or case shall be readily available when the box or case is liable to be needed, and whose name shall be plainly indicated in a prominent place near the box or case.

(4) Nothing except appliances or requisites for first-aid shall be kept in a first-aid box or case.

(5) In the following cases, namely—

(*a*) in the case of a site where more than 500 persons are intended to be or have been employed at any one time in operations to which these Regulations apply and the number so employed is for the time being more than 250, and

(*b*) in the case of a site at which more than 250 persons are intended to be or have been so employed and which is more than 10 miles from a hospital and at which the number so employed is for the time being more than 100,

there shall be provided and maintained in good order and in a clean condition a properly constructed ambulance room with equipment at least up to such standard as may be prescribed. The room shall be used only for purposes of treatment and rest and shall be in charge of a suitably qualified person who shall always be readily available during working hours, and a record shall be kept of all cases of accident or sickness treated at the room.

(6) For the purposes of Regulation 80, numbers employed shall be reckoned according to the largest number at work at any one time.

Shelters, accommodation for clothing, and facilities for meals

81.—(1) Subject to the provisions of paragraphs (2) and (3) of this Regulation there shall be provided at or in the immediate vicinity of every site where persons are employed in operations to which these Regulations apply, for the use of persons so employed and conveniently accessible to them—

(*a*) adequate and suitable accommodation for taking shelter during interruptions of work owing to bad weather;

(*b*) adequate and suitable accommodation for depositing in a dry place clothing not worn during working hours, other than special protective clothing used on occasion for work, coupled with such arrangements as are reasonably practicable for drying such clothing if wet;

(*c*) adequate and suitable accommodation for the deposit of special protective clothing used for work and kept, when not in use at or in the immediate vicinity of the site, coupled with such arrangements as are reasonably practicable for drying such clothing if it becomes wet;

(*d*) adequate and suitable accommodation, affording protection from the weather and including sufficient tables and seats or benches, for taking meals, with facilities for boiling water and adjacent facilities for washing the hands;

(*e*) an adequate supply of wholesome drinking water at a convenient point or points and clearly marked "Drinking Water" or patently intended to be used as such.

(2) For the purpose of paragraph (1) of this Regulation :—

(*a*) accommodation shall be deemed to have been provided for the use of persons employed if specific and effective arrangements have been made for those persons to have access to and use of that accommodation;

(*b*) in considering whether adequate accommodation of any kind is being provided at any time and place regard shall be had to the number of persons who appear to be desirous of using such accommodation at that time and place;

(c) in considering whether accommodation is conveniently accessible account may be taken of any transport provided at appropriate times for persons employed.

(3) Accommodation required under sub-paragraph (d) of paragraph (1) of this Regulation shall, where the Superintending Inspector for the Division by written certificate so directs, include facilities for warming food, and, where the Chief Inspector certifies in writing that he is satisfied that the facilities, if any, for obtaining meals at or in the vicinity of the site are in the circumstances of the case inadequate, that amongst the persons employed on the site there exists or is to be anticipated a substantial demand for a canteen where appropriate meals can be purchased and that a canteen should be provided, shall include a suitable canteen where such meals can be purchased by such persons. Any certificate issued by a Superintending Inspector for a Division or by the Chief Inspector hereunder may at any time at his discretion be revoked or varied.

(4) If any separate building or structure is provided for the purpose of sub-paragraph (b) or (d) of paragraph (1) of this Regulation it shall not be used for the deposit or storage of building materials or plant if such deposit or storage unreasonably interferes with its use for the purpose for which it is provided.

Inhalation of dust and fumes to be prevented

82. Where in connection with any grinding, cleaning, spraying or manipulation of any material, there is given off any dust or fume of such a character and to such extent as to be likely to be injurious to the health of persons employed all reasonably practicable measures shall be taken either by securing adequate ventilation or by the provision and use of suitable respirators or otherwise to prevent inhalation of such dust or fume.

Lead compounds and other poisonous substances

83.—(1) Where any persons are employed in a process in which a lead compound or other poisonous substances is used there shall be provided for the use of the persons liable to come into contact with such compound or substance adequate and suitable facilities for washing which shall include nail brushes, soap and towels.

(2) For the purposes of the Regulation "lead compound" means any material containing lead which, when treated in the manner prescribed by rules made under Section 7 of the Lead Paint (Protection against Poisoning) Act, 1926, yields to an aqueous solution of hydrochloric acid a quantity of soluble lead compound exceeding, when calculated as lead monoxide, five per cent, of the dry weight of the portion taken for analysis.

16 & 17 Geo. 5. c. 37.

Protection of the eyes

84. Where there is carried on any process specified in the Second Schedule to these Regulations suitable goggles or effective screens shall be provided to protect the eyes of persons employed in the process.

PART VII.—MISCELLANEOUS

Fencing of machinery

85. Every flywheel and every moving part of any prime mover, every part of transmission machinery and every dangerous part of other machinery (whether or not driven by mechanical power) shall be securely fenced unless it is in such position or of such construction as to be as safe to every person employed or working on the site of the operations as it would be if it were securely fenced.

Prime movers and other machines

86.—(1) Every prime mover and other machine intended to be driven by mechanical power (being a prime mover or machine used or intended to be used in operations to

which these Regulations apply) shall, unless constructed before the date of commencement of these Regulations, be so constructed that the following parts of such prime mover or machine are securely fenced or are in such a position or of such construction as to be as safe as they would be if they were securely fenced :—

all revolving shafts, fly-wheels, couplings toothes gearing, friction gearing, belt and pulley drives, chain and sprocket drives and all projecting screws, bolts or keys on any revolving shaft, wheel or pinion.

Provided that the foregoing requirements shall not apply to a pulley coupling or other part of a prime mover or machine intended for connecting to the prime mover or machine means of transmitting motion from the prime mover or from or to the machine as the case may be, other than means of transmitting motion from the prime mover to the machine where the prime mover and machine are constructed as a combined unit appliance.

(2) Paragraph (1) of this Regulation shall not be deemed to relieve any contractor or employer of workmen or other person of his responsibilities under Regulation 85.

Mechanically propelled vehicles and trailers

87. Mechanically propelled vehicles and mechanically drawn trailer-vehicles owned, hired and operated under the control of or used by a contractor or employer undertaking operations to which these Regulations apply and used for conveying workmen, goods or materials for the purpose of such operations shall, when being moved at a site where such operations are carried on (whether or not workmen, goods, or materials are actually being conveyed on the vehicle at the time)—

(*a*) be in an efficient state, in efficient working order and in good repair and not be used in an improper manner;

(*b*) be driven or operated only by a trained and competent person over 18 years of age, except that it shall be permissible for the vehicle to be driven or operated by a person over 18 years of age who is under the direct supervision of a qualified person for the purpose of training;

(*c*) not be used to carry a load greater than a load specified as a safe load in a certificate or other document which shall have been obtained from the makers or from a competent person and clearly marked on the vehicle;

(*d*) not be loaded so as to interfere with the safe driving or operation of the vehicle.

Explosives

88. Explosives shall not be handled or used except by or under the control of competent persons with adequate knowledge of the dangers connected with their use and steps shall be taken to see that, when a charge is fired, persons employed are in positions in which, so far as can reasonably be anticipated, they are not exposed to risk of injury from the explosion or from flying material.

Generation of steam, smoke and vapour

89. Measures shall be taken to prevent, so far as practicable, steam, smoke or other vapour from being generated on the site and obscuring any part of the work, scaffolding, machinery or plant where any person is employed.

Protection from falling material

90.—(1) Any place on the site of the operations at which any person is habitually employed shall be covered in such manner as to protect any person who is working in that place from being struck by any falling material or article.

(2) Scaffold materials, tools and other objects and material (including waste material) shall not be thrown, tipped or shot down from a height where they are liable to cause

injury, but shall be properly lowered; in any place where proper lowering is not practicable and also where any part of a structure is being demolished or broken off adequate steps shall be taken, where necessary, to protect persons employed from falling or flying debris.

Lighting of working places, etc.

91. Every working place and approach thereto, every place where raising or lowering operations with the use of a lifting appliance are in progress, and all openings dangerous to persons employed, shall be adequately and suitably lighted.

Projecting nails and loose material

92.—(1) No timber or material with projecting nails shall be used in any work in which they are a source of danger to persons employed or be allowed to remain in any place where they are a source of danger to such persons.

(2) Loose materials where not required for use shall not be placed or left so as to impede the passage of persons upon platforms, gangways, floors or other places on the site used for such passage, but shall be removed, stacked or stored so as to leave such places free from obstruction. Materials shall not be insecurely stacked in a place where they may be dangerous to persons employed, or so stacked as to overload and render unsafe any floor, roof or other part of a building.

Construction of temporary structures

93. Any temporary structure erected for the purpose of operations to which these Regulations apply not being a scaffold or a structure to which Regulation 35 applies, shall be of good construction, sound material and adequate strength and stability, having regard to the purpose for which it is used.

Avoidance of danger from collapse of structure

94.—(1) All practicable precautions shall be taken by the use of temporary guys, stays, supports and fixings or otherwise where necessary to prevent danger to any person employed through the collapse of any part of a structure during any temporary state of weakness or instability of the structure or part before the structure is completed.

(2) Where any work is carried on which is likely to reduce so as to endanger any person employed the security or stability of any part of an existing building or of a building in course of construction all practicable precautions shall be taken by shoring or otherwise to prevent danger to any person employed from the collapse of the building or the fall of any part thereof.

Prevention of drowning

95. Where on or adjacent to the site of any operations to which these Regulations apply there is water into which a person employed is in the course of his employment liable to fall with risk of drowning, suitable rescue equipment shall be provided and kept ready for use and steps shall be taken to arrange for the prompt rescue of any such person in danger of drowning. Where appropriate and reasonably practicable, secure fencing not less than 3 feet in height shall be erected near the water to prevent such fall.

Wet paint on iron and steel work

96. No ironwork or steelwork on which there is wet paint, other than paint for the purpose of jointing, shall be moved or manipulated on the site of the operations :

Provided that this Regulation shall not apply to moving or manipulation in connection with the painting of ironwork or steelwork on the site.

Safety nets, sheets and belts

97. If the special nature or circumstances of any part of the work render impracticable compliance with the provisions of these Regulations designed to prevent the fall of any persons engaged on that part of the work, then those provisions shall be complied with so far as practicable and except for persons for whom there is adequate handhold and foothold either there shall be provided suitable safety nets or safety sheets or there shall be available safety belts or other contrivances which will so far as practicable enable such persons who elect to use them to carry out the work without risk of serious injury.

Appointment of experienced persons to supervise safe conduct of work

98. Every contractor and employer of workmen who undertakes operations to which these Regulations apply and who normally employs more than 50 persons in such operations at any one time, shall specifically appoint in writing one or more persons experienced in such operations and suitably qualified for the purpose (whose name or names shall be entered on the copy or abstract of these Regulations required to be posted up in accordance with Sections 115, 107 or 108 of the Factories Act, 1937) to be specially charged with the duties of advising the contractor or employer as to the observance of the safety requirements of these Regulations, and as to other safety matters, of exercising a general supervision of the observance of these Regulations and of promoting the safe conduct of the work generally.

This Regulation shall not be construed as preventing two or more contractors or employers from jointly appointing the same person or persons to perform some or all of the aforesaid duties for those contractors or employers, whether for a particular site or for a group of sites.

The duties assigned to a person appointed under this Regulation by the employer or employers appointing him, including any duties other than those mentioned in this Regulation, shall not be such as to prevent him from discharging with reasonable efficiency the duties assigned to him for the purposes of this Regulation.

Registers, certificates, etc.

99.—(1) The registers for reports and particulars required by Regulations 20, 34, 57 (4) and (5), 71 (*b*) and 75 shall be kept on the site of the operations for which the register is being used and when there are no such operations shall be kept at an office of the employer for whom the inspection, test or examination as the case may be was carried out :

Provided that in the case of a site where the employer has reasonable grounds for believing that the operations will be completed in a period of less than six weeks, the employer may keep the registers of reports required by Regulations 20, 34 and 75 at his office.

(2) All other registers prescribed and every other certificate or document required to have been obtained for the purposes of these Regulations shall be kept either on the site of the relevant operation or at an office of the employer for whom the entry in the register was made or the certificate or document was obtained or of the owner of the appliance or plant to which the certificate relates.

(3) Registers and certificates required by these Regulations shall at all reasonable times be open to inspection by any of H.M. Inspectors of Factories, and the person keeping any register or certificate shall send to any such Inspector such extracts therefrom or copies thereof as the Inspector may from time to time require for the purpose of the execution of his duties under the Factories Act, 1937.

PART VIII

Prohibited sale or hire of machinery

100. The provisions of subsection (2) of Section 17 of the Factories Act, 1937 (which prohibits the sale or letting on hire of certain machines which do not comply with the provisions of that Section) shall extend to prime movers or machines which do not comply with the requirements of Regulation 86 of these Regulations.

Dated this 31st day of May, 1948.

G. A. Isaacs,
Minister of Labour
and National Service

FIRST SCHEDULE

Chains and Lifting Gear excepted under Regulation 65 (as to heat treatment)

(1) Chains made of malleable cast iron.

(2) Plate link chains.

(3) Chains, rings, links, hooks, shackles, swivels and eyebolts made of steel or of any non-ferrous metal.

(4) Pitched chains working on sprocket or pocketed wheels.

(5) Rings, links, hooks, shackles and swivels permanently attached to pitched chains, pulley blocks or weighing machines.

(6) Hooks, eyebolts and swivels having screw-threaded parts or ball-bearings or other case-hardened parts.

(7) Socket shackles secured to wire ropes by white metal capping.

(8) Bordeaux connections.

SECOND SCHEDULE

Processes to which Regulation 84 applies

(1) Dry grinding of surfaces of metal, stone, concrete or similar materials by means of a wheel or disc driven by mechanical power.

(2) Cutting, dressing or carving of stone, concrete or similar materials by means of a portable tool driven by mechanical power.

(3) Chipping or scaling of painted or corroded metal surfaces or wire-brushing of such surfaces by mechanical power.

(4) Cutting out or cutting off of cold rivets or bolts from any structure or part thereof.

(5) Welding or cutting of metals by means of an electrical, oxy-acetylene or similar process.

THIRD SCHEDULE

EXTENT OF EXCLUSIONS UNDER REGULATIONS 2 (3)

Regulation	*Extent of exclusion*	*Exceptions and conditions*
34	Requirement (*c*)	
36	The whole Regulation	
37	Requirement (*b*) and the requirement relating to guard-rails and toe-boards	
38	The whole Regulation	
40	Paragraphs (2) and (3)	
44	Paragraph (3)	
45	Requirement (*f*)	
46	The whole Regulation	
52	The whole Regulation	
53	Paragraph (2) and requirement (*b*) of paragraph (3)	
54	The whole Regulation	
57	Paragraphs (2), (4) and (5)	Save that where the crane is specially erected for use in the operations to which these Regulations apply, the crane shall before such use be tested in accordance with paragraph (4), and a record shall be kept of the particulars of the tests and paragraphs (5) shall then apply.
58	Sub-paragraph (*c*) of paragraph (1)	If there are available to any person using the chain, rope or gear means of ascertaining its safe working load.
60	The whole Regulation	
64	The provisions relating to the keeping of a register	
65	Sub-paragraph (*b*)	

CHAPTER 12

STONEWORK AND MASONRY

I. STONEWORK

GENERAL

THE stones used in building are divisible into three main classes :

(1) *Sedimentary.*—These were deposited in layers under the waters which at one time covered the land. Being so deposited, their section is stratified; that is to say, they show in greater or less degree the layers as deposited. In many of the sedimentary stones, these layers are hardly distinguishable, except under a microscope, unless there are impurities present that give the difference in colour to the planes of sedimentation. Under a microscope the particles will all lie in one direction in a sedimentary stone, indicating the flow of the current in the water. The sedimentary stones include : Limestones, Sandstones, and Shales, all of which are more or less stratified.

(2) *Igneous.*—The stones in this division owe their origin to volcanic action, and include : Basalts, Granites, and Syenites, all of which are unstratified.

(3) *Metamorphic.*—These stones, which may have been originally either sedimentary or igneous, have been transformed by heat, pressure, crystallisation, and infiltration. They include the Dolomites, Marbles, and Slates.

Without going at all deeply into the matter of the geological formation of the earth, it seems beyond dispute that at some very remote period in the world's history it consisted of gases only ; and that at some still very remote period, ages after the first, these gases began to liquefy, and with their liquefaction there was also a solidification, hence land and water, and the molten masses and gases still in the interior of the earth existed at extremely high temperatures. Hence, too, the atmosphere surrounding the earth.

Of the rocks in class 2—the Igneous, which had their origin in the molten slate—some solidified deep within the earth's surface, and are known as *Plutonic Rocks,* of which *Granite* is the example. Others solidified in conditions of great rapidity of cooling, and are called *Hypabyssal Rocks,* and of these *Porphyry* is the example. Whilst a third solidified at or near the outer edge or surface comparatively quickly, and are termed the *Volcanic Rocks.*

Continuing the story of granite, which is typical of all, this rock, where exposed, was subjected to the corrosive action of the weather, frost, rain, and wind, and also to the transporting action of both water and wind, causing the transference and deposit in beds and in layers or strata of decomposed granite—still granite chemically, but physically different, and also mixed with new materials. Then as the deposits grew in depth, they were subjected to great pressure, with the result that the *Sedimentary Stones* were formed, which include the Sandstones and Clays, Limestones, and a large variety of intermediate deposits.

Then came certain compression and shearing forces acting on certain of the sedimentary and the igneous rocks, which brought into being rocks having not only strata parallel with the base, but lines of cleavage at an angle with the base. Of these slate is the best example used in building of that class of stone known as *Metamorphic*.

Classification.—Thus the stones used in building are classified as follows:

1. Granites . .	Igneous.
2. Sandstones 3. Limestones . .	Sedimentary.
4. Marbles and Slates	Metamorphic.

The terms denoting the classification are helpful when considered in conjunction with the foregoing outline description, as on the nature of the formative process of the stone depends its physical characteristics, and on these depend the possibility of the uses to which any particular stone can be put in a building. On its physical properties and its chemical composition also depends the stone's powers of resistance to, not only natural atmospheric wear, but to pollutions of the atmosphere, caused mainly by coal smoke in cities and manufacturing areas.

Consequently, in order to enjoy the study of masonry with appreciation of the reasons why, rather than just to learn the bald facts, it is requisite that something of the physical and chemical properties of the various stones used should be studied and understood.

Characteristics of the Varieties of Stone.—*Minerals.*—It should be accepted as a starting-point that the materials composing all stones are, in the first place, minerals. It is customary to regard minerals as only certain recognisable substances which have passed into everyday nomenclature as mineral. However, as has been said already, minerals may exist in gaseous and liquid form as well as in solid. It is, however, a fair description of minerals to say that they are the materials which form the earth's crust, and, as has also been already pointed out, the earth's crust having been originally gaseous, it is natural to expect that in the process of solidification the resultant minerals should possess crystalline form.

So far as building stones are concerned, this crystalline formation exists in two ways: (1) the texture is crystalline, that is, the rock is

built up of crystalline structures, and (2) the mineral is itself a crystal.—Of the first class *Granite* is the best example, being built up of quartz crystals; and of the second, *Quartz* indicates the crystalline mass formation.

These mineral crystals are, of course, combined or built up in a variety of ways, and in combination with and cemented to other substances, which accounts for the different kinds of stone.

As no very helpful purpose would be served by giving the names and characteristics of the various minerals composing the earth's crust, and as it is impossible to study minerals from written descriptions in any case, it is of interest in passing to record that only about one dozen minerals enter very largely into the composition of the stones used in building.

However, a few notes on *Quartz*, which is an oxide of silicon, will be of interest, as quartz in some form or other is found in building stones.

Quartz, as a transparent crystal, is known to most people. In granite it appears in grains, moulded on other minerals. Mostly quartz in granite is clear and glasslike, and imparts that dark grey which is so typically a characteristic of granite.

As will be supposed, quartz is the basis of sandstones and grits, and it is also a cementing material in some of the limestones.

Granite, as has been said, is an igneous rock, and as the name implies, its composition consists of granular crystalline particles of quartz, feldspar, and mica.

The igneous rocks having solidified deep within the interior of the earth's crust, it is natural to expect that they should have been subjected to very great pressure, and are mainly to be found at great depths. This latter, however, is not always so, because, owing to volcanic eruptions, granite with other stones ordinarily to be expected at great depths were heaved upwards, and occur in veins between other surfaces.

This, then is the explanation of the classification of granite as a *Plutonic Igneous* rock, being consolidated at very great depth and under very great pressure, and all the granites are built up of the same essential minerals—feldspar, quartz, and mica.

Feldspar is in colour either white, grey, yellow, pink, or red, and may easily be detected in the polished surface of granite. Its form is that of irregular grains often grouped in clots, though it may appear in the form of crystals.

Quartz is also present in irregular grains moulded on other minerals. In colour it is dark grey as a rule, but may occur as yellow, pink, blue, and violet.

Mica.—The form of mica present in granite is that known as dark mica. This is brown in colour, and appears as crystalline plates. It is recognisable in granite from its comparative softness and its irregular outline.

In Cornish granite these three minerals are very easily to be distinguished by the naked eye. However, to study the texture most satisfactorily, a

thin section should be examined under the microscope, when the main characteristic of granite—its composite crystals—may be detected.

The best granites for building purposes are those in which the distribution of the minerals is regular throughout the mass.

The chief characteristics of granite in the mass are to be seen in the quarries. These are technically termed joints, rift and grain, veins and dykes. The joints are both vertical and horizontal, and may extend for over 50 feet. "Rift" gives a tendency to the granite to split more easily in one direction than another. The direction of rift is indicated by the crystals of any one of the minerals lying in the same direction. "Grain" is the direction in which the stone may be split with ease next to that afforded by rift. "Dykes" are streaks of similarly constituted rock, but of younger formation, traversing the granite in any direction. If these dykes are numerous they cause an interference with the quarrying operations.

A Good Granite for building purposes may be known by its fineness of grain, high percentage of quartz (which has been said is silica = sand); and its main property as a building material is that it is practically uncrushable and indestructible. Its resistance to pressure is from 1,000 to 2,000 tons per square foot; and its weight per cubic foot from 160 pounds to 200 pounds.

Granite is obtained from the following quarries in England:

Devon and Cornwall known as Cornish granite, the chief quarries being the Penrhyn. The stone is coarse in texture, with white, irregular-shaped prisms of feldspar, 1 inch long, with grey quartz and dark mica.

Leicestershire, known as Midland Counties granite, is not of the usual formation, and varies a good deal in colour from light to dark.

Shap Fell Granite is found in Westmorland, and is of a distinctive brownish red colour. It is used as a decorative stone, as it polishes well, an example of which may be seen in the columns at St. Pancras Station.

Of Scotch Granite the best known is the *Aberdeen*, though it also occurs in Kirkcudbrightshire and Kincardineshire, also in the Highlands and the Western Isles.

The Aberdeen granites used for building have a bright appearance, the darker greys being used in ashlar work.

The Peterhead is a form of Aberdeen granite used largely as a polished stone for internal decoration, the red Peterhead being used exclusively for this purpose.

Granite is also found in Ireland, the Isle of Man, and the Channel Islands. In the Isle of Man the quarries are called the Dhoon Quarries, and are near Ramsay. The stone from these quarries is of medium texture and light grey colour.

The Irish Granite is quarried near Newry, in co. Down, and is of a greenish grey or grey-blue colour.

In the Channel Islands the quarries are situated near St. Brelades, in Jersey.

Foreign Granites are imported from Scandinavia, and are used for kerbs, sets, and engineering work.

Granite is also quarried in the United States of America, Canada—where it is plenteous, but the quarries are not yet developed—and in France, Austria, and Germany.

Other Igneous Stones.—Though granite is the best known igneous stone used in building, there are others of the same class which are quarried, and when used, found eminently satisfactory as building stones. Amongst these are :

Syenite, which, owing to the absence of quartz, is easier to work than granite, but is comparatively rare ; *Diorite,* also free from quartz ; *Gabbro,* which is found in Cornwall, Herefordshire, and North Wales ; *Porphyry,* also found in Cornwall ; *Porphyrite,* found in Somerset and in Leicestershire, where it is used for roadmaking ; *Dolerites,* of a dark green to bluish black colour, known locally as " greenstone," and found in Cornwall and Devon.

Volcanic Rocks, which are used as building stones largely on the Continent, include : Rhyolite, Trachytes, and Andesites. In England these stones are used mainly for roadmaking.

Limestones.—Limestones consist mainly of carbonate of lime, even up to 80 per cent. Its formation is due to the deposit of shells and calcareous skeletons in seas or lakes. Oolitic limestones resemble in texture ossified fish roes.

Limestone varies considerably from a heavy, crystalline stone to a soft-grained friable chalk. They are divisible into those mainly *Organically* formed and those mainly *Chemically* formed.

The first class include *Shell* limestones, both sea and fresh water ; the *Carboniferous* limestones ; the *Foraminiferous,* which are formed by microscopic organisms having a tiny shell ; *Coral Limestones* ; and *Bryoza Limestones.*

The *Chemically* formed limestones include the *Tufa* and the *Oolitic.* The former is deposited from springs warmed by volcanic activities : the most important building stone being *Travertine,* which has a high value as a decorative stone.

The Oolitic Limestone is composed of layers of carbonate of lime in rings, and its appearance and texture are well known in Bath and Portland stone.

Magnesian Limestone, of which the best known is the Mansfield stone, is a combination of carbonate of magnesia and lime.

Colour and Varieties of Limestone.—The colour of limestone varies considerably, including bright red, orange, yellow, grey, and white, some even black.

The reds, and any tint owing its origin to red, come from the presence of iron in the form of oxide. Greys, blues, and blacks are caused by carbonaceous matter.

The best-known varieties are :

Portland (best known).—A granular texture. White to light brown colour. Found in Dorset.

Bath.—Fine-grained Oolitic. White or light yellow, cream to buff—weathers well set on natural bed. Quarries at Box Ground, Monk's Park, Nr. Bath ; also Farleigh Down, Corsham Down, Coombe Down, which last is a fine-grained stone, very suitable for carved work.

Ancaster, Lincolnshire.—Cream to buff colour.

Beer Stone.—Quarried near Axminster, in Devonshire ; has a chalk basis, cream coloured, and turns grey—crushing strength equal to Portland. Suited to internal work and carving.

Chilmark, Wiltshire.—Light brown, even grain—good weathering.

Ham Hill, Somerset.—Yellow-grey. Hard, coarse grained—shelly—used in panels for decorative purposes.

Kentish Rag.—A blue-grey, difficult to dress, and is consequently mostly used in rubble walling externally, but not suitable for internal work. In weathering it tends to flake. Near Maidstone it is quarried for use on roads, and is much used for garden work.

Ketton, Rutlandshire.—Even texture—cream to yellowish brown—soft when quarried, but hardens on exposure.

Hopton Wood, Derbyshire.—The best known of the carboniferous limestones—cream coloured—compact—suitable for carving and polishing. Hardens on exposure, and out of doors it weathers evenly. Used in the Victoria and Albert Museum, Kensington.

Mansfield, Nottinghamshire.—A magnesium limestone. Warm yellow-brown colour—crystalline. Used in Houses of Parliament.

Doulting Stone, quarried near Shepton Mallet, Somerset.—Light brown to cream—uniform in texture. Soft—earthy appearance, growing paler on exposure. Used in Wells Cathedral.

Painswick Stone, Painswick Quarry, near Stroud, Gloucestershire.—Soft pale cream—strong—durable—most suitable for interior work in steps, chimney pieces, hearths, etc.

Clipsham Stone, Oxfordshire.—Oolitic—medium grain—buff colour—suitable for copings and monumental work. Used in Ely Cathedral.

Foreign.

Caen Stone. Normandy.—Pale cream yellow—unsuited for external use, but very suitable for detailed carving used internally. Used in Henry VII Chapel, Westminster.

Longchamp.—Resembles Portland.

Savonières Stone.—Pale yellow, shelly, oolitic—medium fine grain.

Limestones are also formed in Austria, Belgium, Germany, and Scandinavia.

Sandstones.—*The Sandstones* are stratified sedimentary stones, which were produced by the rotted and disintegrated rocks, like granite, being carried away and deposited by water in layers. Of these, the finer-grained quartz waste forms the sandstones, and this, when first deposited as mud, forms clay, shale, and eventually slate.

Evidence of this depositing action is to be seen in ripple marks, and sometimes in footprints of birds and impressions of plants on the layers of the finer sandstones.

These grains of the original components of the disintegrated stone are cemented together in sandstones in a variety of ways and by a variety of substances. The cementing substances are siliceous, calcareous, and argillaceous. The red, brown, and yellow tints in sandstones are due to oxide of iron.

Varieties of Sandstone.—*Cragleith Stone,* near Edinburgh.—Calciferous, a light grey stone, fine grained, very durable. Original quarries exhausted. Suitable for general building and monumental work.

Robin Hood Stone, Yorkshire.—Carboniferous, grey, fine grained, used for general building. Sharp arris and smooth face.

Forest of Dean.—Calcareous, compact, grey, blue, and pinkish grey. Good weathering properties, very hard

Blue Pennant, Glamorganshire.—Very hard.

Bristol Pennant, Gloucestershire.—Carboniferous, fine grained, hard, blue colour. Good for steps and landings ; also used in engineering.

Darley Dale, Derbyshire.—A millstone grit—light buff and light grey—fine grained, and takes a good arris—weathers well.

Howley Park Stone, Yorkshire.—Carboniferous—light brown—fine grained—matrix silica—good smooth finish and sharp arris—hard and durable. Good for general building work—sculpture and monumental.

Wealden Stone, Sussex.—Ferruginous. The weald was originally a freshwater lake. Fine grained—light yellow with brown specks. Does not weather well in polluted atmosphere.

Marbles.—*Marbles* are metamorphosed limestones or dolomites, their original structure having been changed by pressure, their being completely crystallised, and their primitive forms obliterated. Marble, being capable of taking a very high polish, is used for decorative work.

Varieties.—*Purbeck Marble,* Dorset.— Several varieties—oolitic limestones—not true marble—reddish brown—greenish grey—light blue-grey. Fossils—takes a good polish, but does not retain it.

Hopton Wood Marble, Middleton, Derbyshire.—Not a true marble. Carboniferous limestone. Built up of molluscs, corals, light grey and drab. Takes a high polish.

Ashburton Marble, Ashburton, Devonshire.—Fossils of coral—dark grey with red veins and almond-shaped patches of white.

Iona Marble, Argyllshire.—Metamorphosed dolomitic limestone. Pale green and pure white grounds with veins of light green.

Irish Marbles.—Irish green and Irish black. Black from co. Caiton—green from co. Galway.

Foreign.

Greek Cipollino.—Pale green with dark green curved bands like an onion.

Swiss Cipollino.—Pale green—dark green veins, usually straight.

Genoa Marble.—Dark green—veins of light green and white.

Vidraco Marbles.—Pale bluish fawn with veins of reddish brown.

Tino's Greek.—Bright green, fine veins of light green. Suitable for outside work.

QUARRYING

Stone is obtained from quarries by blasting and wedging the blocks away from the solid. It is partly worked in the quarries, and then sent to the stone yards, where it is further worked and finally finished in the manner to be described.

The Portland Quarries afford one of the best opportunities for studying, not only the operations of quarrying, but also the disposition of strata, the vertical jointings already referred to, and the risings or horizontal joints and fissures.

The operations consist in excavating the waste, which is stone unsuitable for building purposes, and in levering the blocks of stone away from the solid mass into positions from which it can be hauled to the surface.

The whole of the Portland peninsula consists of an upheaval of oolitic limestones, and except for the connecting link of Chesil Beach, is virtually an island. Chesil Beach, it may be noted in passing, affords an excellent example of a water-borne deposit in process of formation. It consists in its entire length of seventeen miles of pebbles. In width this ridge varies from a quarter to half a mile, and its average height is 50 feet. The pebbles are mainly calcareous, and in the process of deposit and the pressure generated, there is no doubt below them, in process of formation, a rock bed of the future. The point of main interest to the present subject is that the pebbles have been carried by water from Bridport district and from Devonshire. The process of the wearing down of the pebbles is to be seen in the fact that at the Portland end of the beach there are pebbles weighing ten or twelve pounds, but under the influence of the drift of currents and pressure as they are driven farther into the bay, they become smaller and smoother, until pebbles are to be found there weighing only a few ounces.

Portland " isle " consists almost entirely of quarries. The rocks are well exposed in the cliffs and the section is easily seen. This, so far as the stone useful for building purposes is concerned, consists of three beds in the order named—the *Roach*, the *Whit Bed*, and the *Base Bed*.

But as these beds are from 50 feet to 60 feet below the surface, very considerable excavation of unsuitable material has to be undertaken before they are reached. Originally the stones were quarried from the vertical face on the north side, Sir Christopher Wren having obtained the stone from this part for the building of St. Paul's Cathedral. The Portland beds referred to had been exposed here by a landslide, so saving the heavy excavation works now required farther inland.

Over the Portland beds are superimposed what is known geologically

as the Purbeck beds, the section of which is to be seen farther eastwards round the coast at St. Aldhelm's Head, which is just before Swanage is reached, going towards it from Weymouth by sea. Weymouth, it should be recalled, is the bay of which Portland Bill forms the most westerly extension.

The above outline description is interposed here because in this small area of the country, as excellent an example as could be wished for of what has been given here in explanation of the formation of the earth's crust is to be seen. Consequently, to anyone wishing to see in actuality the method of this formation, a visit to that district is advised.

Over the Portland beds lie first a very thin soil, and under this, about 8 feet to 10 feet of rubble. Under this again is about 3 feet of slat, which is shivered stone, such as was mentioned in explanation of the formation of sandstone deposits from rotted granite and other igneous rocks. Next come alternating beds of clay and slat and a hard limestone unsuited to building, until the *Dirt Bed* is reached. This bed is of particular interest, as in it are to be found evidences that at this level at some period there grew a forest. In the earth are to be seen embedded and, of course, fossilised, the trunks of trees and vegetable matter. The bark is to be clearly seen on the trunks of the trees, and even the annular rings are to be detected in the sections of the tree trunks. The roots are in the dirt bed, whilst the trunk and branches extend upwards into the stratum of yellow stone above. Whether the burial at such a depth of such a forest was due to a sudden upheaval or due to the processes of time affords an interesting study, and in either event it affords indisputable testimony of the age of the earth as being far greater than was previously supposed.

Under this most interesting dirt bed is a stratum of Portland stone known as *Top Cap*, which, though unsuitable for building operations, is used in engineering.

Under the next stratum, known as the *Skull Cap*, the Portland beds proper are found.

The Roach is a pale buff oolitic limestone, the stratum being from 3 feet to 4 feet thick. This stone is full of cavities, which were originally filled with fossils, but these have been destroyed by the waters of percolation. Many of these cavities still retain the impression of the fossil shell, and are known locally as "horse heads." This stone, owing to its coarse texture, is not really suited to building work, but is much used in harbour construction and other heavy engineering.

The *Whit Bed*, which is also termed the top bed of freestone and the brown bed, is next under the roach bed. This affords a fine-grained oolitic limestone of pale brown colour, which whitens on exposure. The thickness of the bed varies from 8 feet to 10 feet. The texture of this stone varies, containing patches of broken shells and others of softer material, and occasionally flint nodules are found. This stone works very well, and will take a sharp arris.

Current bedding is to be noted in parts of the bed which affords further evidence as to the method of its formation.

The Base Bed consists of a fine-grained oolitic limestone paler in colour, being cream, and softer than the whit bed, and does not weather so well in exposed positions. It is not actually next to the whit bed, there being a rough bed of flints and roach between. Suitable for carved work; takes a good arris, and faces up well.

When examined under the microscope, the shell formation of *Portland Stone* is easily detected with light patches of cementing material in between. The chemical composition of the stone is that of an impure calcium carbonate, with often a small percentage of oxide of iron occurring which may be seen in the brown patches. The variations in the matrix which binds the shells are thought to be the cause of the variations in the powers of resistance to decay possessed by Portland stone. Evidence of this decay is to be seen in the stone used in St. Paul's Cathedral.

The Quarrying Operations at Portland are in the nature of handwork, and as has been indicated, a good deal of waste has to be removed before the required beds are reached.

In these beds, the roach, whit bed, and base bed, there occur vertical fissures as well as planes of deposit. These large fissures, often as much as 2 feet in width, are termed locally "*gullies*." Starting from these gullies, the stone in huge blocks is gradually wedged away from the main rock, and under the block in the base joints other wedges and levers are driven, and the stone is split parallel to the base. This process is termed "*Reaming*," and the blocks vary in size according to the position of the joints, some weighing as much as 100 tons. The blocks are then roughly squared and raised by cranes on to trollies, on which they are hauled to the railway sidings and to barges.

The further operations necessary to prepare the stone for use in the buildings are performed in the stone yards, largely by machinery, as is later described.

Quarrying by Blasting.—For this operation, which is the usual method employed in quarrying the igneous rocks such as granite, a shaft is first sunk. The blasting charge—a light one for the first operation—is laid in an inclined vertical jointing.

Quarry Water.—In many quarries the underground water amounts to a very considerable quantity, which is actively instrumental in assisting in the formation of the rock. This water has to be pumped out of many workings continuously and the stone when first quarried contains a considerable amount of water known as *Quarry Sap*, which must be dried out before the stone is used in the building, or its presence will increase the tendency to decay, owing to its containing salts and other chemicals drained from the earth, known as *Overburden.* During the seasoning of the stone these chemical impurities are brought to the surface and deposited thereon by the evaporated water, and can be removed when the stone is worked.

After the first light charges in blasting, the stone will be found to have shifted, widening the fissures sufficiently for the workmen to insert heavy charges that will blow the stone from the face. It is then split up into the sizes required and roughly squared and straightened.

In some quarries the facing is performed before dispatch to the yard, either by hand or by pneumatic chisels.

WORKING THE STONE

It will be clear, from what has been said of the manner of the formation of building stones, that they will have the greatest strength if set in a position in which their strata may offer the greatest resistance to stress of load imposed upon them. This position is that in which they lay in the quarry, *i.e.* with the natural bed at the bottom. To resist the weather, stone should be set so that the strata are equally effective. The subject of planes of cleavage and minor fissures enters largely into the matter of the liability or otherwise of stone to decay; but the general rule, that a stone should be set parallel to its natural bed, may be accepted. An experienced mason can generally tell from the texture of the stone in section which is its natural bed, and in addition the blocks are usually marked to that end. Some stones, the igneous, and some of the metamorphic class, have no natural beds, and so may be laid on any face; whilst in thick bedded sandstones both normal and false current bedding occur. Stone laid otherwise than on the natural bed is very liable to decay by flaking off parallel to the natural bed.

A practical tip in the matter of discovering the natural bed of stone is to inspect it after it has been subjected to heavy rain, when the stone in the neighbourhood of the bed will be darker than elsewhere.

Yards and Machinery.—*Stone yards*, several fine examples of which are to be seen in the Lambeth district of London, since the introduction of machinery, rather resemble large engineering shops. Handwork is now almost entirely superseded by machinery, except, of course, for carving. Not only surfacing and sawing, but also cutting, mouldings, and polishing are now performed by machinery.

Frame Saw.—For cutting the large roughly squared block into slabs of a size convenient to work, a machine known as the frame saw is used.

On an overhead frame several saws are fixed at distances apart necessary to give the required thickness of slab. The block of stone is then raised by a crane on to a trolly, which runs on rails under the frame carrying the saws. The blades of the saws are either corrugated or plain:—the corrugated being used for Portland and the plain for cutting marble. They function forwards and backwards, and are supplied with Bridport sand to aid the cutting operation, which is accompanied by a steady stream of water.

Note.—The amount of waste stone powder carried away from a large stone yard in the water outflow suggests that valuable possibilities are still awaiting discovery.

The sand is carried down by the water to the bottom of the cut or kerf, and so wears away the stone by the friction of the saw plate, rather than cutting in the sense it is generally understood.

Carborundum.—For smoothness of cutting, carborundum mixed with shellac is pressed round the saw blades when hot. This carborundum sawing is suitable for lighter work rather than for speed.

Diamond Saws.—Saws are now fairly generally used which have bands around their perimeters. These bands carry sockets into which diamonds are fitted. The best-known saw of this type is the *Anderson Duplex Saw.* The stone in this operation is fed up to the saw in a similar manner to that last described, on a moving table, the motion of which is controlled and may be increased or slowed down. It is customary to run fast whilst the saw is in the interior of the stone and to slow down at the edges to prevent splitting. The table may also be quickly approached in order that no time is lost in bringing the stone into position to be sawn. The operations of the saws are controlled by a gearbox containing machine-cut gears, giving four feeds, which may be instantly changed as desired by a lever conveniently placed.

The saw is fitted with two 6-foot diameter blades, giving a cut 30 inches deep. The tables under are 12 feet long by 6 feet wide. A 35-h.p. motor drives the saw, and a 6-h.p. varied-speed motor is used for the table. The tables may be together or separate, and when separate have each a motor, then allowing a greater freedom of movement.

Anderson's Simplex Cross-cut Diamond Saw is a development of the above, in which the saw moves over a stationary table. The blade is any size up to 5 feet, and gives a cut 2 feet deep, and the action permits of stones 9 feet in length being sawn. Both diamond and carborundum saws are used ; the carborundum being most suitable for cutting marble.

For Surfacing and Finishing planing and moulding machines are used. The moulding machines are now capable of cutting mouldings of any required design, and internal mitred angles may be formed The machines being fitted with a reversible head, cut the stone both during the forward and the backward movement of the table.

Messrs. Anderson also supply rubbing beds and polishers and pneumatic hammers for working marble and granite.

Circular Stone Columns are turned on lathes in a manner similar to wood.

PROPERTIES OF STONE

Appearance.—The appearance of building stones is naturally as varied as their origin and formation, but there are certain characteristics which all classes possess in common, rendering them suitable for building purposes.

There can be little doubt that a stone is best suited for use in that district in which it is quarried, and except for the most expensive class of building, suitability in this respect is likely to be increased rather than depreciated by the growing cost of transport and the comparative lightness and ease

of handling of the many and ever-increasing substitutes for stone. Though the style of our national architecture, if any, can no longer be determined by the nature of the rocks of our country—unless we are to examine sections of poured concrete—it could not be deemed otherwise than as a loss were the use of stone in buildings to die out. Such a calamity may seem a pessimistic vision, until one of the essentially stone districts, such as the Cotswold stone district in Gloucestershire, is visited, and it is found that those so much admired and typically characteristic stone-roofed cottages have been replaced by patent tiles imported from the Continent !

The Qualities which all stones suitable for building purposes should have are as much of a negative nature as positive. They should be free from stains denoting chemical impurities. There should be no earthy particles or flaws, cracks, vents, clay pockets, nor sand holes.

The texture should be uniform, and the colour of that of the best stone from that particular quarry. The grain should be fine when the stone is used as a facing, and the section should show clear and crystalline. The coarser-grained stones will be found most suitable for use as pavings—stairs and corridors—and in any position in which it is desirable to provide a non-slip surface.

Durability.—The durability and other properties of stone are known mainly as the result of experience gained from use ; but in addition these matters have all been made the subject of close chemical and physical research. Some additional knowledge, however, is necessary, since the experience gained as to the unsuitability of certain stones in some districts is appreciable, mainly from signs of decay, of which they give evidence. This being of a negative character, still leaves something to be found out as to the reasons why and methods of prevention. Further, quarries are by no means inexhaustible, occasions having been experienced, in fact, when the supply from a chosen quarry was not sufficient to complete the job in hand. The result of this was that stone from another quarry had to be used to finish the job, and though it was thought that the second stone was similar in every respect to the first, it was not long before a serious mistake in this became evident in the rapid decay of the stone.

The effect of the atmospheric conditions also may be quite different, not only in stone from the same quarry in different districts, but also upon the stone from different parts of the same quarry, even though used in the same building.

Absorption.—In this respect the absorptive properties of any stone are a matter of considerable importance, not only from the decaying effect of damp, but from the far more active destruction of frost in the expansion caused by the freezing of water within a stone. When the means by which water finds entrance to a stone and the hair-like nature of the channels through which it must pass are considered, the tremendously destructive effect of the sudden expansion caused at the same moment all over the interior of a stone at the instant the water contained turns to ice will be realised, especially when it is recollected that 10 parts of water by volume

become 11 parts by volume of ice. What actually occurs then is a series of miniature pipe bursts all over the interior of the stone, with the natural result that the stone flakes off.

Expansion and Contraction.—Though possibly surprising, it is a proved fact that stone expands and contracts in accordance with variations of temperature. Indeed, this alteration in dimension is often the cause of decay, in that it occasions the cracking of a stone otherwise quite sound, and even if the stone itself remains sound, the mortar and pointing becomes cracked and admits rainwater that would otherwise be excluded. The result is that weak spots in the interior of the stone which would have remained protected then become subjected to all the destructive agencies of the atmosphere, the worst of which are the acids carried to a building from the atmosphere of cities by the wind and rain.

A point of additional interest in this matter is that experiment has established the fact that, after a stone has been caused to expand by heat, it does not contract to its original dimensions.

The actual expansion shown in figures of any piece of stone may appear as a slight matter scarcely worthy of notice; but when this stone is placed in a wall of any length and the fraction becomes multiplied to that extent, it will be seen that the matter assumes more serious proportions.

Seasoning.—Allied to the matter of the effect of frost is that of freeing stone from the water naturally contained when the stone was in the quarry. This is known as " quarry sap."

When the stone is freshly quarried it will, in many instances, still contain a considerable quantity of quarry sap. As this renders the stone easier to work, it is appreciated by the stonemason rather than otherwise. But when the stone is once enclosed on all sides but the face, or it may be on all sides if in the interior of a wall, then it is a difficult matter to get rid of this moisture from its interior.

In some stones there is naturally more quarry sap than in others. Bath stone, for instance, should be given twelve months in the open air to season.

Decay may be started by this internal water and the chemicals which it contains, as the origin of quarry sap is water which has percolated to the stone in the quarry from the vegetable soil above. As the water does eventually dry out the chemical impurities will crystallise. Consequently, all stones, in varying degree, require a period of seasoning in order that the quarry sap may dry out in part, if not entirely. The result of such seasoning is that the crystallisation will occur on the face of the stone before it is worked, and when these operations are undertaken in the yard the crystal-covered portions will be removed.

Porosity, as distinct from absorptive properties, is the percentage of pore space in a stone. The tables which are given and the tests by which the facts contained in them are obtained give rather figures of saturation than porosity.

The simplest practical method is that of soaking the stone in water and weighing before and after, but the results so obtained are only approximate. However, for the purpose of comparing the relative absorption properties of any stones this will be found sufficiently accurate.

The method above described for testing absorption, however, is not always reliable, as it is difficult to be certain that all the air in the pores has been replaced by water; an apparatus has therefore been designed by which the water is forced into the specimen.

The following table given by Warnes gives the results of tests for porosity and absorption of the best-known stones.

	Porosity.	Water Absorption.
	Per cent.	*Per cent.*
Grey Granite	0·12	0·10
Hopton Wood Stone	8·36	4·7
York Stone	11·94	4·70
Portland Stone	12·80	7·20
Doulting Stone	14·46	10·87
Red Mansfield Stone	14·98	4·58
Monk's Park Stone	20·51	7·51
Box Ground Stone	22·32	7·75

With reference to the above table Warnes states: "It will be noticed, on reference to the table above, that a high porosity does not mean a correspondingly high water-absorption figure, and as to a certain extent the decay of stone is assisted by the amount of absorbed water retained by it, or in other words, the slowness of removal by capillary attraction and evaporation, then a stone possessing a high porosity value will not necessarily decay more rapidly than one with a low value."

Capillary Action.—The word capillary is derived from the Latin word *capilla*, which means a hair, and the connection is with the action which develops in a liquid like water when confined in a fine-bored channel comparable with a hair.

To understand this action certain elementary experiments are helpful as explaining what is termed the "surface tension" of water, though it is not suggested that surface tension and capillary action are the same.

If an ordinary pin be thoroughly dried, and, after being sprayed with some powdered French chalk, is very gently lowered on to the surface of some water in a glass, it will be seen, if the pin point is examined through a strong magnifying glass, that it actually repels the water, as if it were pushing it downward and causing a depression before it enters. Next, as the pin becomes wet and is withdrawn, it will be seen to draw the water with it. This is not, as might be imagined, anything to do with the French chalk, which is only an additional precaution to ensure that the pin is dry, as a dry pin without French chalk will act in the same manner. The pin can be seen definitely pushing down the surface of the water just as it would india-rubber.

The water at the sides of the tumbler used as above should be examined through the magnifying glass, when it will be seen that all round the edge the water is raised into a sort of rim, where it comes into contact with the inner surface of the glass.

For the second experiment a clean sheet of glass is required, and on to this a fine dust known as "lycopodium" dust is powdered, though any other dust, such as a powdered chalk, would serve. A drop of water—very tiny—is then gently dropped on to the surface of the glass, when it will be found to resemble a ball of quicksilver, the water acting as though it were surrounded by a membrane which prevented it from sticking to or wetting the glass. The comparison with quicksilver, however, goes no further than this, as quicksilver and any other liquid which does not wet its containing vessel does not form a rim at its edge, but on the contrary its upper surface is curved upwards to the centre.

The force noted in the experiments with the water is termed "surface tension," and this develops into capillary action in the following manner.

In the first instance the water finds entrance into the pores of the stone, which may for the sake of this explanation be considered as hair-like tubes, though of course they are not continuous. As with the glass, the sides of the pores are, at the moment of the water first entering, dry; consequently, the surface of the minute column of water is at first retarded by the friction caused by the surface tension of the water against the dry side of the hair tube, and if magnified, the surface of the column of water would at first be seen to resemble that of quicksilver. However, it is not long before the water wets the side of the tube, and then a creeping action is set up by which the raised rim is formed at the edge of the surface. Then as the water becomes absorbed, it tends to rise in the centre, after which another rim is formed just above the last. So the creeping action continues much after the manner of the progression of a worm, the extension of one part pulling after—by surface tension—the rest of the body—in the case of the worm, the head end pulling the body, and in the case of the water the edge pulling the centre of the surface. And as the surface of water cannot rise without the body of water underneath following we get in time the hair tube filled with water by the apparently impossible action of water flowing upwards. This is the explanation of capillary action.

Wearing.—It is natural that stone should start to decay at its weakest parts, and this is why such stress is laid on uniformity of texture. High winds have considerable wearing power, and when these carry sharp grit they become in the nature of a mild sand blast, and bore out the softer parts of the stonework. Also any projections, sharp arrises, and carving, often become worn down and rounded in a surprisingly short time by a prevalent wind. Once holes are started in this way the particles of the stone itself carry on the destruction with increased rapidity, and are whirled round and round in a similar way to which pebbles are lodged

in sinkings on rocks at the seaside. They then bore out holes of considerable size.

With sandstones it is found that their weakness lies in the matrix, or cementing material, and when the quartz grains, which are practically indestructible, become loosened, the action described above is often seen. This destruction of the matrix may be begun by the chemical action of acids in the rainwater, and once begun it is continued by the wind in conjunction with the acids.

When the cementing material in sandstone is of an argillaceous or clayey nature, shale or slate, it is more subject to wear in this way, and such stone should be avoided for building work.

Efflorescence is the white deposit which sometimes occurs on the surface of walls. It is caused by salts present in the walling material or mortar being drawn to the surface as moisture in the wall evaporates. It is not only unsightly, but may disrupt the stone and mortar by exerting pressure behind the surface. As Portland cement contains these free salts it is advisable to use a mortar with only a small proportion of cement.

Although continual washing down removes the salt deposits, every time the wall is penetrated by rainwater further deposits of salts will occur as the moisture evaporates. The trouble tends to decrease as time goes on, but there is no quick cure. In some cases the salts come from the brick backing or from the ground.

On *Granites* the chemicals in the atmosphere have little effect, but extremes of temperature do, as the rates of expansion and contraction of quartz and feldspar are not the same, with the result that the surface will flake off when subjected to excessive heat.

On *Limestones*, which consist largely of calcium carbonate, the sulphuric acid in the air destroys the cohesion, with the result that the stones of this class are the worst sufferers from this kind of decay.

As a general rule the most dense and compact stone is the best for building work, as this characteristic is evidence of its having been subjected to great pressure in its formation.

Iron Cramps.—The use of iron cramps is a frequent cause of decay in stone-work, which, in the past, caused much trouble at the Houses of Parliament. The iron rust expands considerably and cracks the stone.

The Natural Bed.—As has been said, stone should be laid horizontally to the natural bed, the reason being that this is parallel to the layers in which the material was deposited. This bed may be discovered as soon as the stone is worked, the crystals lying flat in the direction of the plane of the bed, and this makes it easier to work in that direction than any other.

Stones in which there is no appreciable layering are most suitable for carved work, as they do not split when worked in any direction.

Slate, which is sedimentary rock of the finer-grained material, was first deposited as mud, and afterwards under pressure became shale and

eventually slate. With regard to the natural bed of slate, as has been explained in Chapter 2, this has been superseded by the Planes of Cleavage caused by pressure acting at an angle to the original bedding plane. It is this characteristic which with others renders slate so suitable a material for roofing, as it can be split along the planes of cleavage into thin plates.

STONE DATA

Stone.	Weight. Cu. feet in pounds.	Crushing Resistance per sq. foot in tons.	Absorption.	Dimensions of 1 ton in cu. feet.	Safe Load per foot super in tons
Ancaster Stone	156	552·6 (Beare)	2·45	—	30
Bath, Coombe Down	128	118 (Beare)	6·2	19½	4
Bath, Corsham Down	129	94·5 (Beare)	11·25	—	—
Bath, Monk's Park	137	223·5 (Kirkaldy)	7·76	—	—
Bath, St. Aldhelm Box Ground	129	107 (Rivington)	7·90	—	—
Beer Stone	132	152	12·15	—	—
Bolsover Moor Stone	152 (Rivington)	484 (Royal Commission)	8·2	14¾	28
Bramley Fall Stone	163	552·2	3·9	15¾	—
Blue Bristol Pennant	172	1,001 (Kirkaldy)	3·6	—	—
Chilmark Stone	154	136 (Kirkaldy)	7·5	16	—
Craigleith Stone	138	802 (Rivington)	3·6	14¾	4
Darley Dale Stone	148	670 3 (Kirkaldy)	3·5	—	—
Doulting Stone	125	104	10·5	—	—
Forest of Dean	152	631	2·82	—	—
Granite Penrhyn	164	1,250	·12	13½	—
Granite Aberdeen	160	1,300	·40	—	30
Granite Cornish	167	1,100	·18	—	20
Hopton Wood Stone	158	806 (Rivington)	4·7	—	—
Ham Hill Stone, Yellow bed	135	207	7	—	10
Ketton Rag	140	101·7	9	15	—
Mansfield Stone, Red	141	463	5	—	11
Marble	—	—	—	13	20
Portland Stone	—	—	—	—	—
Portland Stone, Roach	142·5	—	—	—	12
Portland Stone, Whit bed	132·2	204·7 (Beare)	7·5	15	—
Portland Stone, Base bed	137·3	287·0 (Beare)	6·8	—	—
York (Hard) Stone	—	—	—	14½	17
Slate	—	—	—	—	22

The results given in the first three columns, unless otherwise stated, are from tests by Arthur I. Warnes, in *Building Stones*.

1 cubic yard of walling = 18 feet super of walling 18 inches thick ; and contains 32 cu. feet of rough stone and 9 cu. feet of mortar for uncoursed rubble, and 36 cu. feet of rough stone and 7 cu. feet of mortar for coursed rubble, 30 cu. feet of rough flints and 9 cu. feet of mortar for flint walling (Spons).

II. MASONRY

PREPARING AND BUILDING

Tools Used.—Though there might seem, at first sight, to be as many tools in a mason's outfit as in a carpenter's, they consist, for the most part, of some form of cold chisel and some form of hammer or mallet. The chisels range from round pointed punches to flattened cutting edges

widened out to 2 inches and 3 inches. The edges of both classes of chisels in some are plain, in others serrated or clawed.

The hammers range from pear-shaped wooden tools, known as the mason's mallet, to metal-headed hammers of different weights and shapes for the different stones to be worked.

In addition to these, there are the saw, trowel, straightedge, squares, trammel, and sinker, used for drawing parallel lines to the arris; the scraper for finishing the surface of soft stones; braces, bits, and drills for drilling holes, and gouges used in working mouldings. Steel templates are also used fresh for each job, cut to the outline required for any moulding.

An Axe, and a patent axe having a double head, are used for preparing and finishing granite. The latter has a set of chisel plates bolted to each end of the hammer head.

The Dummy is a form of mallet which, being used with wood-handled chisels, is composed of a composition of lead and zinc.

The Bevel is used for testing the angles of bevels and chamfers, and is a sort of adjustable set square.

Drags are used for finishing the surfaces of Bath stone, made of steel plate and having one edge toothed; *Cocks' Combs* are a form of drag, having curved faces, all toothed, and are used for cleaning mouldings.

A Plumb Bob and a Level complete the average mason's outfit, who, of course, in common with everyone else in the building trade, will possess a 2-foot rule.

Terms Used.—There are certain terms used in describing masonry which have special application to this trade, and as it is necessary to know these before the descriptions of the processes can be rightly understood, they are given here for reference in conjunction with the description of the methods of working stone which follows:

The Face of a stone is the surface exposed to view when the stone is set in the building. The surface selected as a starting surface in the preparation of the stone is sometimes termed the face, and may eventually become the surface exposed to view. But confusion will be avoided if that surface be known as the *Surface of Operation*, *i.e.* the surface selected to start squaring up the stone.

The Return Face is any side at right angles to the face; for example, the side of a building at a corner would expose the return faces of the angle stones.

Beds.—There are two beds, the first being that on which the stone is set when built into the wall; and the second being the upper face when it forms part of a course on which the next course is to be laid.

Joints are the prepared surfaces which abut on stones next to them. The variety of joints used in masonry will be found described below.

Back or Rough Back is the vertical face in the interior of the wall when the stone is built in. This is generally left comparatively rough from finishing with the punch or saw.

Quoins are angle stones which may be set at the corners of a building or at angles to recesses and openings.

Plinth is the name given to a projecting base to a wall, the top course of which is generally chamfered or moulded to the face of the set-back wall above.

Break is the term applied to any recess or horizontal set-back of the line of a wall. Doors and windows may be built in breaks.

An Arris is any external angle or corner on a stone. The exactness of cutting desirable in a stone will be recognised when the method employed in surfacing is studied ; and this explains why, in describing the properties of any stone used in building work, a point is always made of stating whether or not it will take a sharp arris. Stones which will not work up to a sharp arris are more suitable for carved work.

A Closer is the last stone placed in a course of the correct width necessary to fill the gap left, giving the proper adjustment to the joints of the other stones in the course—joints in the face of stonework of certain types are built " breaking joint," as in brickwork.

Mitres are of two kinds :

External—which is the intersection of mouldings at external angles.

Internal—being the intersection of moulds at internal angles.

Stop is the vertical plain face on to which a moulding is returned and finished.

Coping is the top course of a wall—generally weathered to afford protection from rain.

Coping is also the name given to the operation of splitting any block of stone along any line required.

Crown of an arch is the highest part of the arch, at which the *Keystone* is set.

A Kerf is the cut made by a saw in stone.

Quarry Axed is the name given to the rough facing worked on stone in the quarry before dispatch to the yard.

Boning is the operation of adjusting the straightedge in a level plane employed when facing a stone.

Boning Blocks are cubes of hardwood, $1\frac{3}{4}$ inches, used for the same purpose as the last, but for very hard stones such as granite.

Surface of Operation is the face which is first trued in squaring a stone.

Gads are wedges driven into holes cut in a stone to split it.

Quirk, a narrow groove or sinking in stonework.

String Course is a moulded or plain projecting horizontal course.

Marginal Drafts are the four channels first levelled on the upper corners of the surface of operation.

A Winding Surface in stonework is one not in the true plane, and requires re-surfacing.

A Templet is the pattern, in wood or metal, giving the section of the shape to which it is required to cut the stone. *Bed Mould* is another name for the same, though templet is more often confined to use with mouldings.

Scribing is the name given to the operation of marking the outline of the mould or templet on the stone.

The Trammel and Scriber are the names of the tool used in the above operation and for marking lines parallel to the arris.

CUTTING AND SURFACING

As was explained under *Quarrying*, stones are roughly squared before they leave the quarries; and in some quarries the further operations about to be described are still carried on, as also they are in many masons' yards. However, since the introduction of machinery, a great quantity of stone is cut by that means, leaving only additional cutting for fitting on the job. As the mason may be required to perform, by hand, any of the operations carried out by machinery, the following description is given.

The stone arrived at the yard will have had its faces roughly squared and levelled by the pick and axe, and the first operation will be that of *splitting* it to a size convenient to handle.

For Portland and similar stones the operation is termed "*Coping*." Soft stones are cut by the hand saw.

In "Coping," a line along which the split is required is first drawn approximately at right angles to one of the faces across the top surface, and continued down the face as near right angles as can be to the line first drawn. An iron bar is then adjusted under the vertical line and one end is wedged up underneath, the other end being left free, which by its weight assists in the splitting operations.

A V groove is then cut along the lines marked, and holes $1\frac{1}{2}$-inch diameter are sunk 4 inches apart in the grooves. Into the holes punches are driven, each being struck one after the other until the stone is split apart.

Marble is cut by nicking a line on the front and tapping at the back. The holes are drilled in granite with a pneumatic drill or by hand with the tool known as *the Jumper*, which is a chisel having the cutting edge shaped in a cross formation. After each blow with the hammer the jumper is lifted and twisted, so that a sort of slow screw motion is set up. In these holes so bored two *feathers* of iron are placed with a wedge between, which is then driven in.

The success of the operation of *Surfacing* depends on the accuracy with which the marginal drafts are cut and squared, and these depend for their accuracy on the cutting of the first datum line. One face is decided upon as the *Surface of Operation*, and the datum line is then marked on one of the sides just below this face. This line indicates the plane of the surface of operation when finished, and consequently it must be level and square. The tool used in cutting this line is called the *Pitching Tool*, which resembles a cold chisel with the cutting end bevelled on one face and flush on the other. The cutting end is widened out to $1\frac{1}{2}$ inches in width.

A channel about $\frac{3}{4}$ inch is then cut along this line on the upper surface,

resulting in what is termed a *marginal draft.* This is trued up level and square, the straightedge being used to test its accuracy.

Next, either of the opposite corners is cut away down to the same depth and square with the first-cut marginal draft. Then with the square and straightedge a second marginal draft is cut from the first to that corner.

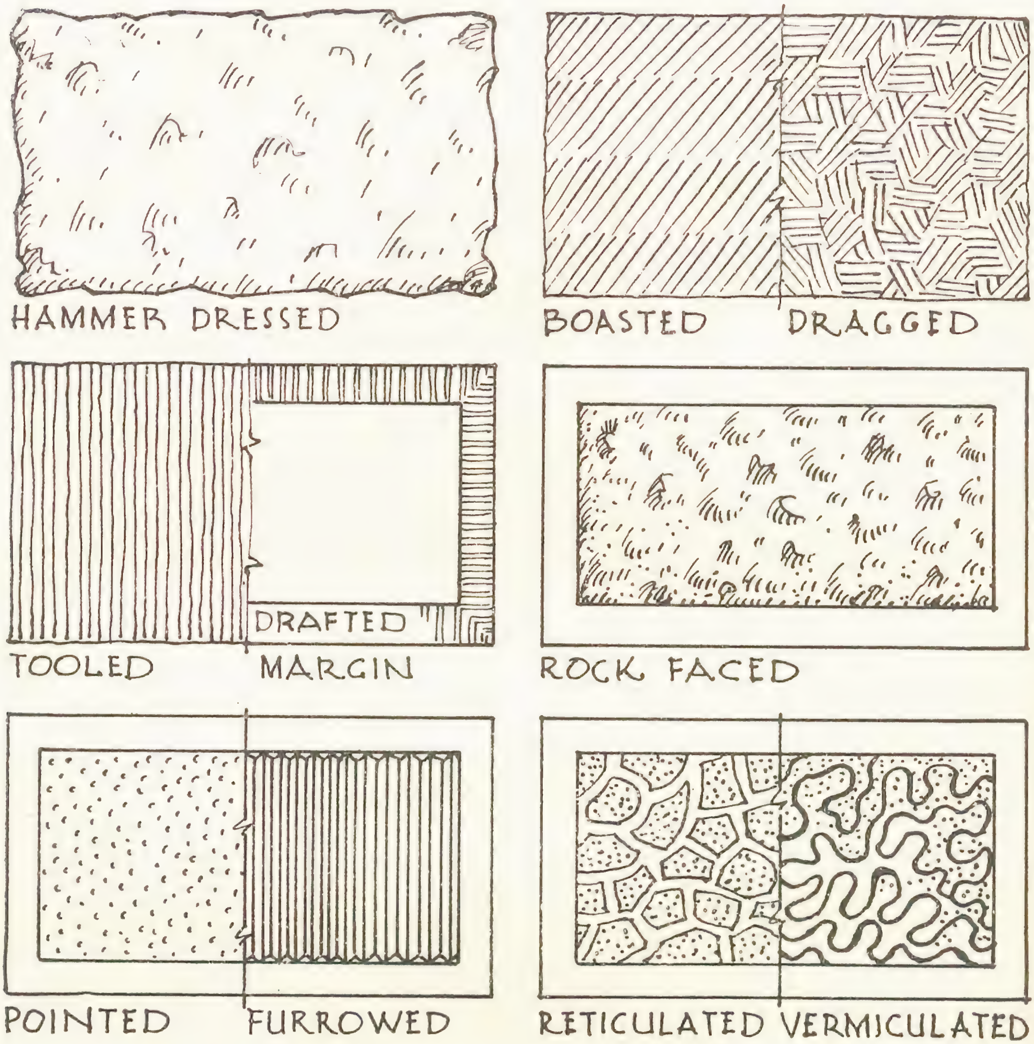


Fig. 176.—Preparation and surface treatments.

The cutting of the third marginal draft must be in the same plane as that of the first, and as this is important to prevent *wind* in the surface, it is performed by the use of straightedges. This operation of sighting the true plane is known as *Boning the Line.* A straightedge is placed with its top edge lined with the marginal draft first cut, and another is held against the face opposite to this, so that its bottom edge lines with the

end of the second-cut marginal draft. By sighting over the top of the nearer straightedge and under the bottom of the second on the right-hand side, the left-hand end of the farther straightedge may be lowered or raised until the site line over the top of the nearer straightedge coincides with the bottom of the left-hand end of the farther straightedge. The rear marginal draft is then cut in the same way as the others. To ensure the accuracy of the last-cut draft, the straightedges are then laid on the top of the front and rear drafts and the lines sighted underneath both ; and when these are found to be in one plane, the side drafts are similarly tested.

Furrows are then cut along the surface of the stone between the original drafts with the hammer and punch. The furrows should not extend quite down to the plane of the drafts, as a certain thickness is required for the next operation, which is performed with the *Claw Chisel and Mallet.*

The Claw Chisel has a widened blade 2 inches wide cut into teeth, preventing the stone from *plucking*, which would result in holes in the surface.

The last operation in surfacing is then performed in working the surface with the mallet and boaster, which is a wide-pointed chisel similar to the last, but without teeth. This operation is performed parallel to the first-cut marginal draft, and is to be continued until the straightedge lies in any direction truly upon the face.

If it is required to square the other faces only, they may be worked from this surface of operations. But where any particular shape is required, this is obtained by the use of a templet or base mould in the manner next described.

In Working to a Required Shape the same principle of first cutting the marginal draft and working to a fixed datum line is followed. The mason is supplied with a bed mould of the section of the shape to which it is required to finish the stone. This has the datum or boning line, which is really the centre line, marked on it, and having laid the bed mould on one trued end of the stone, this boning line must be transferred to the stone, both across the end and down the sawn face at right angles.

Next, the outer edge of the mould is divided into a series of equal divisions, and a series of drafts is worked from these divisions along the surface, testing for squareness with a straightedge and square.

Columns and Mouldings are in these days so much more easily turned and cut by machinery that it is a saving of time and money to obtain them from a stone yard where machinery is used.

TREATMENT OF SURFACING

Stonework used in building may be treated on the surface in a variety of ways, of which the following are the most important :

A Boasted Surface is that left by the mason's boaster, and may

be of a variety of patterns, consisting of the markings left by the tool. The boaster is a flat-bladed chisel with a blade 2 inches wide.

A Punched or Broached Surface has the face marked with a series of herringbone markings cut with the *Point* or *Punch*, after the marginal drafts have been cut.

A Furrowed Surface is one on which small flutings from $\frac{1}{4}$ inch to $\frac{3}{8}$ inch are worked vertically and horizontally across the surface, the side margin being retained.

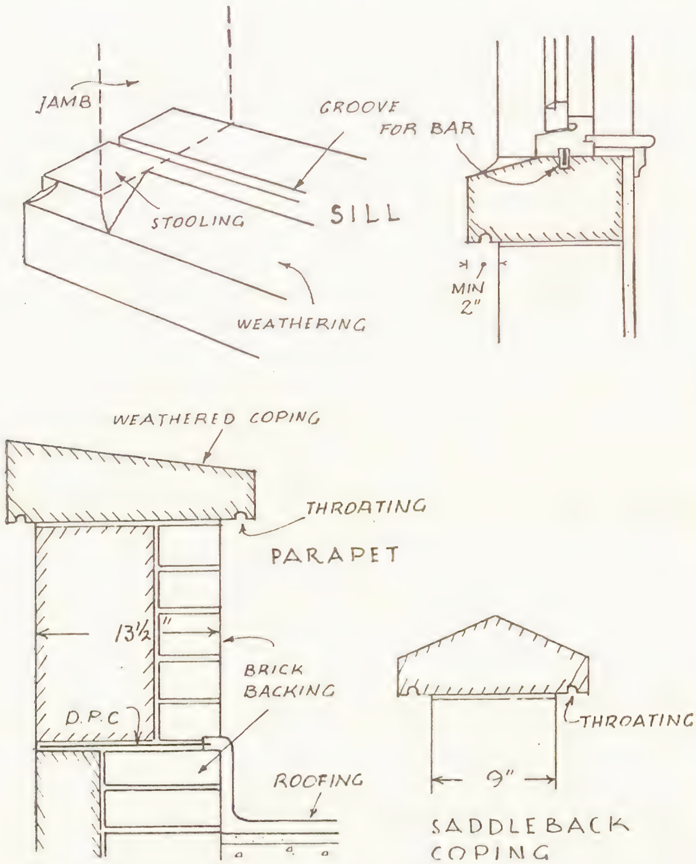


Fig. 177.—(*Top*) Sill. (*Bottom*) Copings.

Chisel-drafted Margin.—This is a finish given to ashlar masonry, the surface of the stone being left rough and the margins worked along the four edges. It is also used in conjunction with certain finished surfaces, such as the Broached already described.

Picked Panel.—In this the panel is sunk below the marginal draft to a depth of $\frac{1}{4}$ inch. After the surface of the panel has been trued with the chisel, it is picked over with a *Sharp Point*, which is a chisel with the edge drawn to a point.

A Pitched Face is the face given in walling known as *Rock-faced Ashlar*. For this facing a *Pitching Tool* is used. This is a chisel having a bevelled edge on the back and a flush face on the front.

Reticulated Quoins.—In these the surface within the margins is punched into a series of irregular sinkings separated by bands of regular width and of geometrical patterns as compared with—

Vermiculated Quoins, in which the divisions are wavy or, as the name implies, wormlike.

In Axed or Chipped Facing the rock is roughly squared with the mason's axe.

Back Setting is the term used in description of such sunk panels as

described in the *Picked Panel*, above. The margin is thus raised above the face of the panel.

A Broached Surface is one in which the stone is dressed to a level face, having diagonal grooves, and is also a *Punched Surface.*

A Dragged Surface is a plain surface treated with a *Drag* and the toothings left to show.

Combing is the finish given to mouldings.

Droved Work is a level face having vertical markings formed with a toothed chisel.

Pointed Work is performed with one of the pointed chisels, rough-pointed or fine-pointed as required.

In Rubbed Work a smooth finish is given without tool markings, by rubbing the surface with grit stone, fine sand, and water.

Rusticated Work is a general term applied to the surface of quoins treated so as to project from the surface of the main walling.

A Tool or Batted Surface is one which has the chisel marks left showing vertically on the face, the " batting " being specified so many to the inch. Templets placed under beams and joints are treated in this manner.

WALLING

In the formation of a gable in masonry the apex is formed of one stone, known as the *Apex Stone*, which is laid on a horizontal base and has an upper member to match the coping.

The Coping is the covering of the gable wall, and as its purpose is to keep walling dry, it is generally weathered, when it is known as a *Feather-edged Coping*. Flat copings are sometimes used on gables, when they are termed *Flat* or *Parallel* copings.

Segmental Copings are those having the upper surface formed in section of an arc; and *Saddle-back* copings have the upper surface sloped or weathered both ways from a ridge, which may or may not be formed at the centre of the section of the stone.

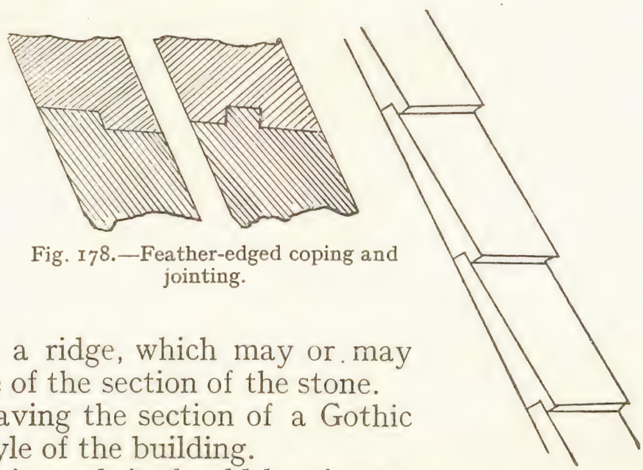


Fig. 178.—Feather-edged coping and jointing.

A Gothic Coping is one having the section of a Gothic moulding cut to suit the style of the building.

Whatever form of coping is used, it should be given a projection from the faces of the wall, and a channel, known as a *Throating* should be cut on the under horizontal surface of the projecting portions, to prevent the rainwater from running down the face of the walling.

Shoulder is the term given stone at the base of the gable, generally having an upper member which forms the base of the coping and is horizontal.

In the height of the coping there are set bond stones known as *Kneelers*, which are built in on a horizontal base into the wall, and have an upper member which forms the coping. The number of kneelers in the run of a gable depends on the height of the gable, as the main purpose of this stone is to prevent the coping stones from slipping.

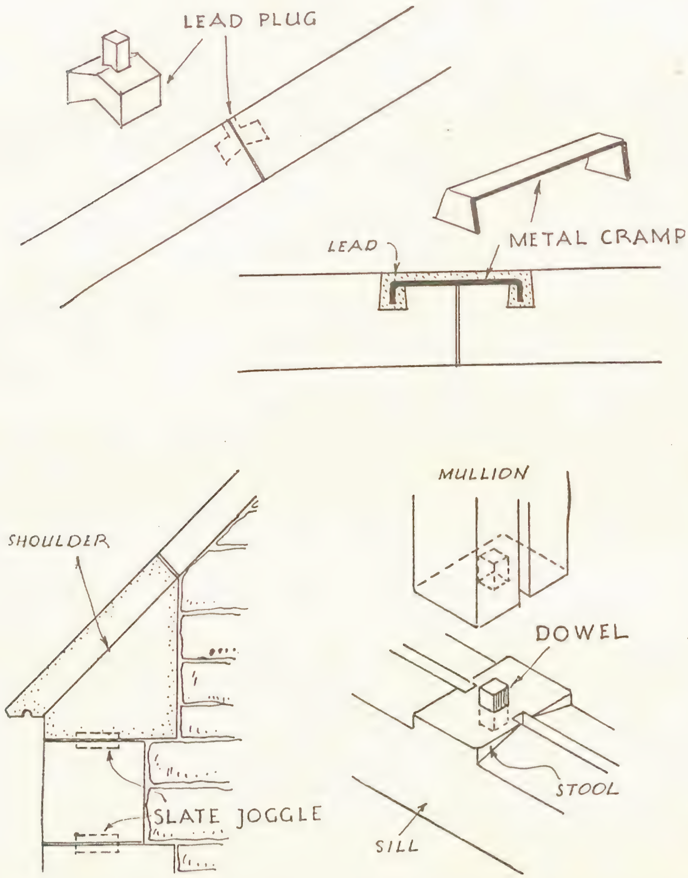


Fig. 179.—Fixings for restraining stones against lateral movement.

Copings are also horizontally used on parapet and other similar walls.

A Corbel Stone is one built in under the shoulder of a gable to afford the required projection against which to finish the eaves gutter.

A Bond Course consists of plain-faced stones composing a course across the face of a wall, generally taking up the line of shoulders, kneelers, and sometimes the head and sills of a window.

Types of Walling.—*Rubble Walling* is formed of either natural-shaped stones or stones roughly squared with the hammer.

In Random Rubble the stones are used as they come from the quarry, or they may be roughly squared with the hammer, but built in without regard to coursing. A certain amount of artistic skill is required in the choice and disposition of the stones in this type of walling, but the strength of the wall will depend for bond mainly upon the mortar. It is required that the stones be so chosen and set that a fairly smooth face and back result, and there should be as few large pockets of mortar as possible. Flat-bedded stones form the soundest rubble wall, and to this end they are frequently dressed roughly with the axe on their bases. No large

stones should be placed on edge, and the filling should be carefully performed, the mallet or handle of the trowel being used to bed the stones well down.

Random Rubble built to Courses.—In this type of random rubble the stones are selected in sizes and worked roughly to courses of irregular height. A horizontal bed to a course should be formed at least from 10 inches to 12 inches in the height of the wall.

Bond Stones should be built in to both of the above types of walling. These are large stones squared and built through the thickness of the wall at least three-quarters of the way from front to back. A bond stone from face to back should be bedded on another from back to face. Bond stones extending throughout the entire width of the wall are not recommended, as, the filling often being weaker than the facing, irregular settlement may take place causing the bond stone to crack.

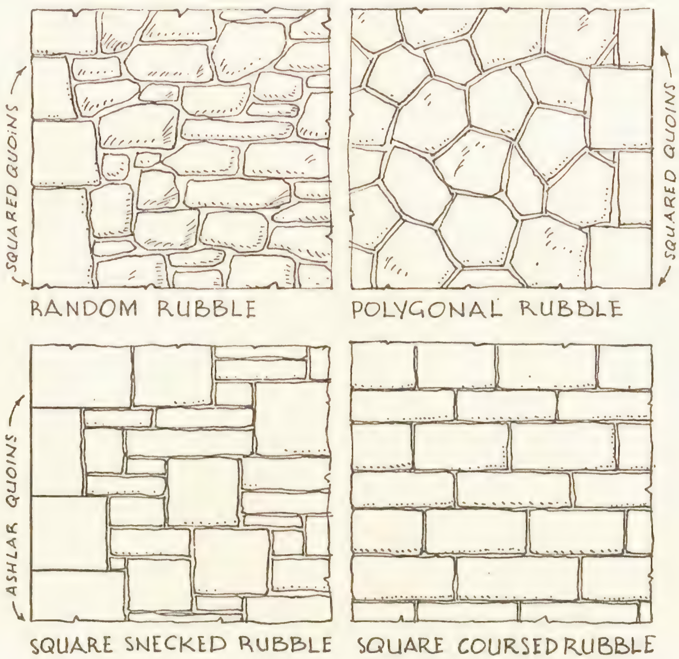


Fig. 180.—Rubble walling.

Snecked Rubble has small rectangular filling stones inserted at intervals, horizontal, though not necessarily continuous, courses thus being obtained. The fit of the stones must be studied in this type. Large flat stones used are termed "blockers," and these should extend at least halfway through the width of the wall. The taller blocks, known as "jumpers," should be at least as wide on their base as their height.

Regular-coursed Rubble is formed of continuous horizontal courses, but of unequal height.

In Polygonal Walling, also termed *Rag Walling,* the stones are set in the wall without regard to bed or coursing. A certain fit between adjacent stones is desirable.

Range Walling applies to Bath-stone walling used internally in which the stones are sawn to heights of about 5 feet, the vertical joints being formed random and the surface being finished with the drag.

Flint Walling is described in Chapter 4, Vol. II, "Miscellaneous

Walling." It is generally used as a fitting between wrought stone dressings and quoins. When the faces of the flints are turned up, it is termed *knapping* or *flush-work*. *Diaper* patterns are sometimes worked in knapped and squared flints alternating with square wrought stones.

Ashlar Walling consists of finely dressed stones of regular shapes and sizes. Ashlar is used only on the face and sometimes the back of the wall, the interior being filled in with rubble or brickwork. The average depth of the courses is from 6 inches to 10 inches, and deeper courses are often used in plinths than in the main walling above. The length of the stones used in ashlar should not exceed two and a half times their height. The finish given to ashlar walling may be plain, rusticated, rock-faced, or chisel drafted, as already described—*Plain Ashlars* are stones given a rubbed, dragged, or polished surface.

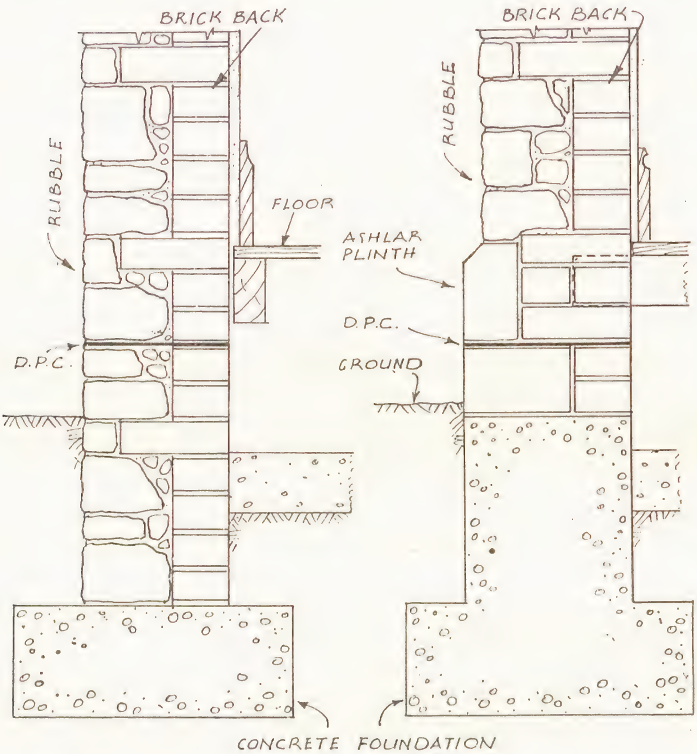


Fig. 181.—Sections showing rubble walling with brick backing.

Quoins are generally built up of ashlar or partly dressed stones — the quoins are formed in sizes to line with the horizontal coursing of the main wall. *Reticulated Quoins* have the face dressed as defined, and *Vermiculated Quoins* are those having sinkings with wormlike divisions worked on the face.

Bases are often worked to the walls of buildings in larger and heavier types of facing. They may be *rusticated*, *i.e.* dressed with a rough face, and have V-shaped margins. The base is often treated as a plinth, when the facing is comparatively thin, and has a squared, moulded, or splayed top. The slab may be flush with or, as is more often the case, project from the face of the main wall over. The moulded or splayed cap should be of greater thickness than the material of the plinth, to give a bonding into the wall. Plinths or bases are often formed of granite, this being suitable on account of its great strength, and that it will, if required, take a polish. Plinths built of marble do not give a satisfactory appearance,

as they are so obviously facings only, and being in a position where great strength is required, are obviously unsuited.

Cross Walls and Partitions in stone-fronted buildings may also be built of masonry, though they are more often in brick in most modern construction. Partitions which do not carry loads, and where lightness is required, are built of breeze, concrete slabs, or some patent clay tile (see Chapter 4, Vol. II).

Toothing.—When it is desired at some later date to continue a wall in a horizontal direction, stones in alternate courses are omitted, those built in being given projections to bond to the later-built walling.

Foundations.—The remarks occurring in Chapter 7, Vol. I, apply to the foundations on which stone walling is to be built even more than they do to brickwork. For instance, it is of greater importance, for the prevention of settlement in stone walls, that the foundations should be such that there is no likelihood of settlement, as the weight of a stone wall is greater than that of brickwork and the bonding is not so regular. Also stonework is more subject to the influence of atmospheric changes, especially to frost, consequently the depth required for the foundation trenches is greater for a stone wall than for a brick wall on the same site. The necessity that the stratification of the foundation bed should be horizontal is also greater for stonework for the same reason, that the bond is not so perfect between stone courses as in brick courses, and where the walling is uncoursed, the need for precaution in this matter is increased.

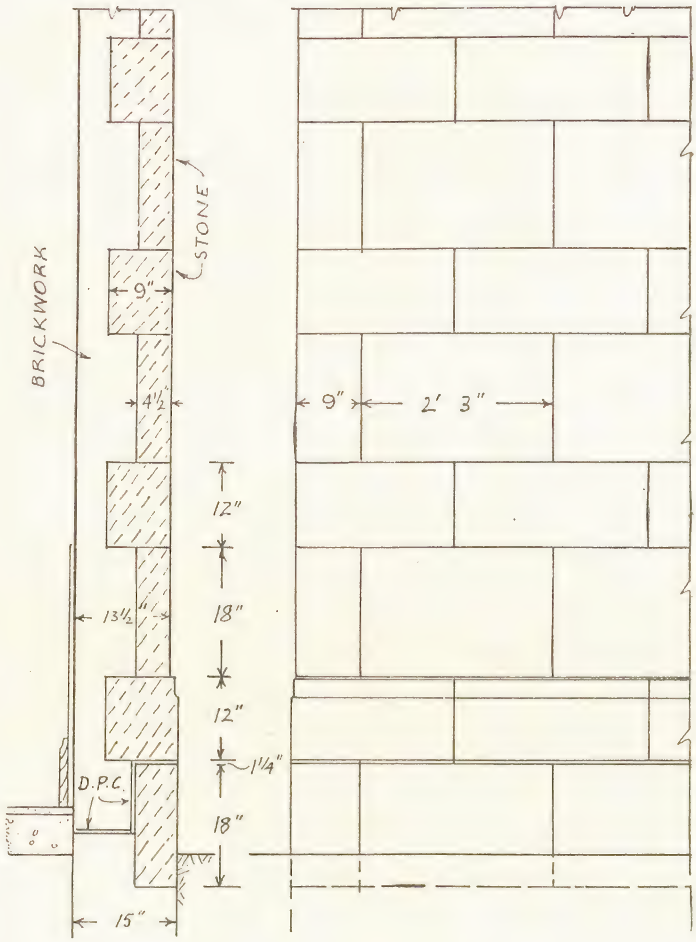


Fig. 182.—Ashlar bonded to brick backing.

Footings.—The spread given to the base of a stone wall should be greater than that given to a brick wall, and the same applies, consequently, to the concrete laid in on the foundations and under the bottom course of the footings to the wall. Projections of a similar nature should be formed at the base of the wall, and the bottom course should be formed of stones about 9 inches deep. At least 12 inches' projection should be given to this course on each side beyond the width of the wall above; and the concrete should be 12 inches wider on each side than this course.

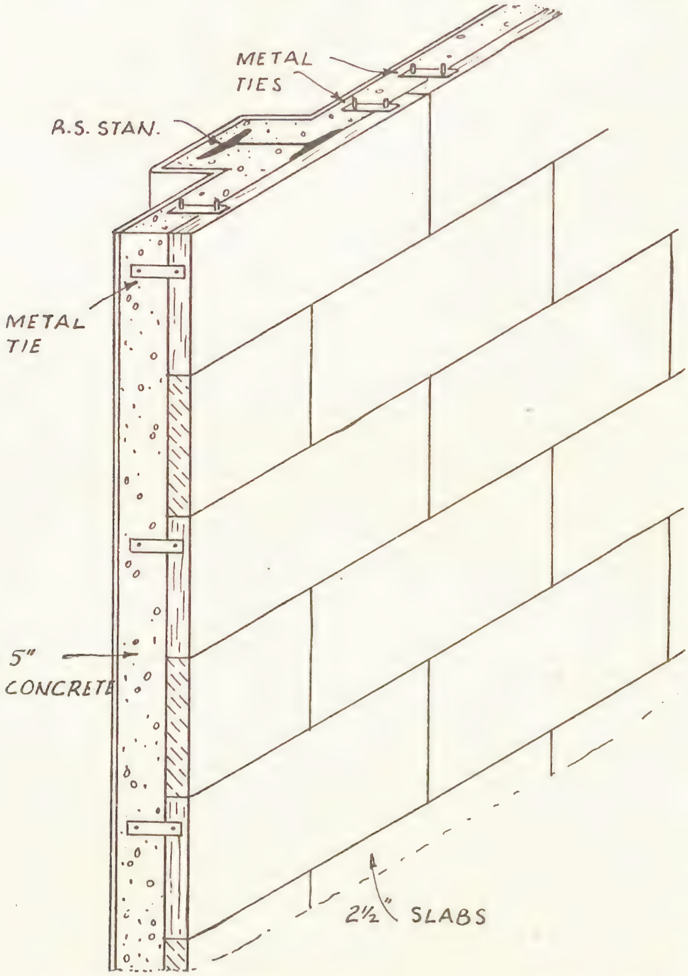


Fig. 183.—Stone facing slabs secured to concrete backing with metal ties.

The depth of the concrete should also be greater than for brick on the same subsoil, and, it should be noted, this applies equally where, as is so often done, the spread footings are built in brickwork if the wall above is solid masonry. Where the wall above is built in brickwork and *faced* only with stone, the depth and width of the concrete may be as directed for brickwork (see Footings, Chapter 7, Vol. I).

The stones in footings should also extend as far through the thickness of the wall as possible, and where the walls are built of rubble, the footings should be at least $\frac{1}{3}$ thicker than for brickwork.

Composite or Faced Walling.—Stonework used in conjuction with brickwork must have the heights of the stone courses the equivalent of a number of brick courses, in order that cross-bonding may be afforded. Consequently, the depth of the stone courses must be $4\frac{1}{2}$, 9, $13\frac{1}{2}$, etc., etc.

The Facing of a stone wall is the stonework on the outside generally wrought in one way as described, and the *backing* is the inside face. In

A HOUSE WITH MASONRY WALLS.
(A. J. Pictor, Esq., Architect.)

A GROUP OF SHOPS WITH FLATS OVER.
(T. P. Bennett & Son, FF.R.I.B.A., Architects.)

between is placed the *filling*, often of another class of stone ; but as has been said, internal bond must be given by bond stones projecting into the filling. In thin walls the facing and backing comprise the wall without filling.

Drains to Foundations and Footings.—As an additional precaution, on a damp site, there should be drains to take off any water from the foundations to stone wall, as stone is even more subject to damp than brickwork.

Dampcourse.—A dampcourse is equally essential in masonry as in brickwork, possibly more so. The omission of a dampcourse would permit of the damp rising up the wall by capillary action with the almost certain result of the decay of the stonework in the base of the wall.

For stonework, slate does not form a suitable dampcourse, as owing to the comparative lack of horizontal bond, the pressure is likely to be unequal, with the result that the slates would crack, and a cracked slate dampcourse is almost as bad as no dampcourse.

Asphalt, or some combination of bitumen and lead, forms the best dampcourse for use in stone walling. This, as with brickwork, should be laid in at least 6 inches above the ground line.

Vertical Dampcoursing.—Any stone wall built under the ground should be faced with a vertical dampcourse of asphalt, or have an internal vertical dampcourse.

It should be noted in this connection that thickness of walling built in stonework affords no protection from damp. Rather the contrary would seem to be the case ; for damp, once it finds entrance to the interior of a stone wall, will spread through the wall, however thick, and a thick wall has less chance of drying out than a thin one. It is within the experience of the author that a cottage with stone walling 3 feet thick, but having no dampcourse, was damper than any brick building ever met with, the walls in the cellar actually running with water at certain seasons.

Loads on Stones as follow shall not exceed :

	Tons per sq. foot
Granite . . .	45–60
York Stone. . .	20
Portland . .	16
Bath	8

DETAILS

Lintels are the stonework framing over the heads of doors and window openings, when not worked in arches. They are best suited to narrow widths, as they are required to carry the load of the walling over. This weight is calculated from the amount of the material within an equilateral triangle having for its base the width of the opening, taken in conjunction with the weight per foot cube of the stone used and the nature of the walling. Additional weight coming from any joists resting on the lintel must also be taken into account.

Whilst concrete properly reinforced is now much more frequently used in the interior of stone-faced walls for carrying the weight, yet narrow openings are still bridged by lintels consisting of a single stone. This must have a bearing of from 6 inches to 12 inches on each jamb at its ends.

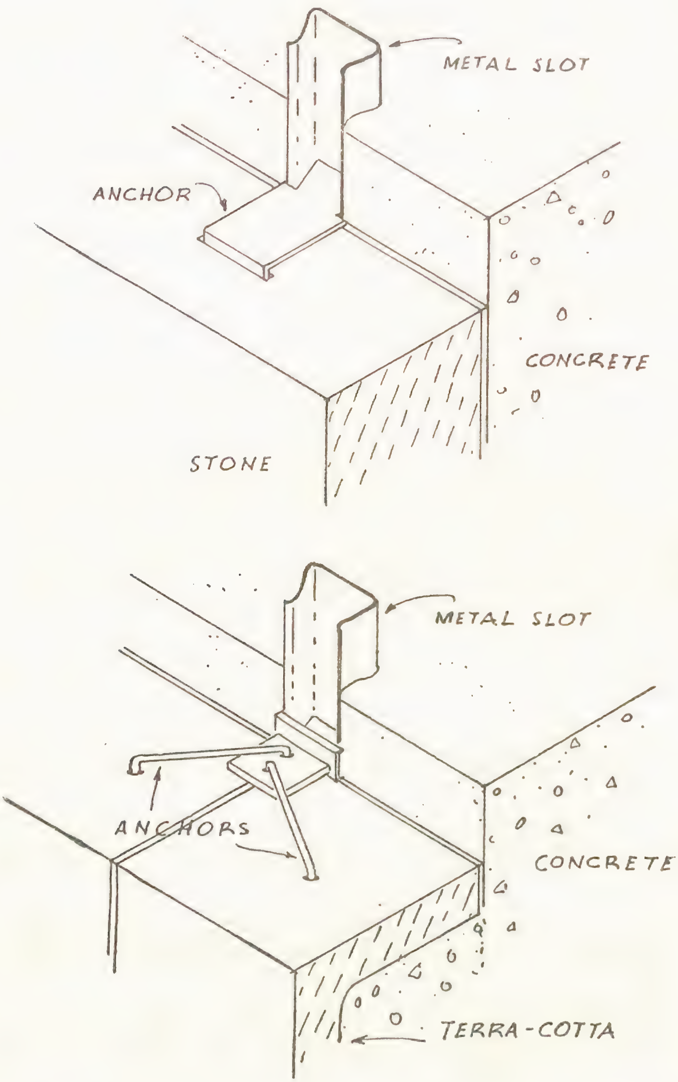


Fig. 184.—Patent fixing slots and anchors for fixing masonry facing to concrete backing.

Flat lintels composed of several stones must be jointed in the same manner as in an arch, *i.e.* the joints are formed at angles, the lines of which, if produced, would converge to a centre within the width of the opening. Such flat arches are generally backed by a concrete lintel which carries all the weight except that of the stone facing.

In design lintels may be flush with the face of the walling or project in whole or part, carrying mouldings known as a *hood mould*. In either case the under horizontal surface of the lintel should be throated.

Arches.—As suggested above, openings of greater width require arches, having blocks which support one another by transforming the vertical downward pressure into a lateral pressure, block against block.

There are a variety of arches used in masonry, and the terms used in connection with them are the same as those used in brickwork (see Chapter I, Vol. II), with the addition of the following terms applicable to stonework only :

Voussoirs are the individual arch stones of wedge shape, which comprise

the arch, and the joints between which would, if produced, meet at the centre from which the arch is struck.

The Keystone is the topmost arch stone placed centrally over the opening and generally enlarged or in some decorative manner more pronounced than the Voussoirs.

The Springers are the lowest arch stones, and generally have one face bedded horizontally on the abutment of the arch. The abutment is the solid masonry forming the side of the opening. When the top surface of this abutment is cut at any angle to start the arch, as it sometimes is, it is called a *Skew Back.*

The Bed Joints to arch stones are the faces which come together in the joints.

A Spandrel is the triangular space between the outer ring, or *Extrados*, of the arch and the course lining with the crown of the arch. This in stonework is often moulded round and filled in with carving.

A Respond is a projection from which an arch springs from a wall face as at the end of a colonnade. The actual stone forming the respond is either a corbel or the cap of a half pier or column.

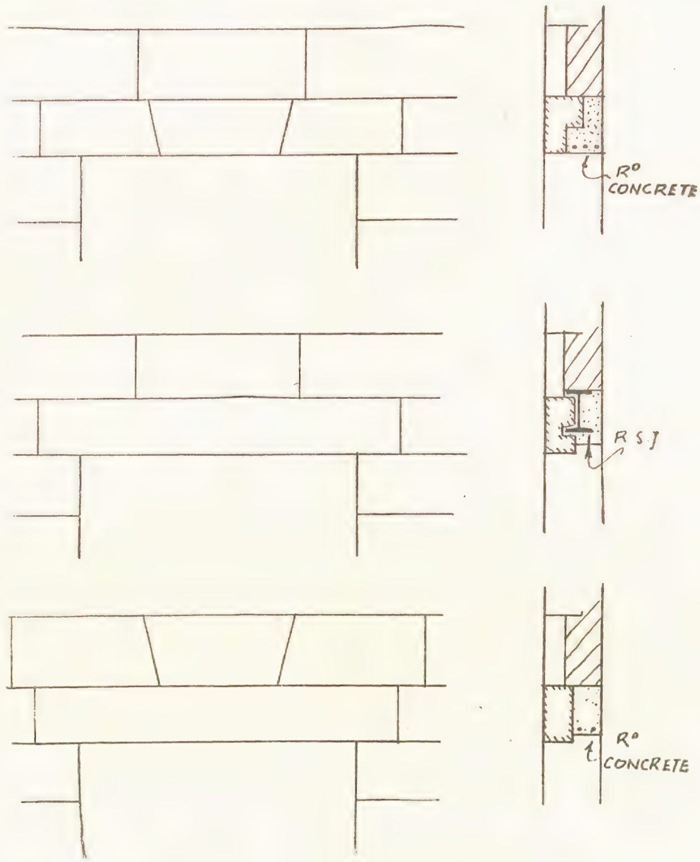


Fig. 185.—Lintels.

The Archivolt is a moulding running round the outer ring of an arch, and is generally worked on the top of the voussoirs themselves.

A Corbel is a stone built to project from the face of a wall for the purpose of carrying a beam or truss.

The Cornice is a projecting course, the term being generally applied to that finish given to the top of the walling; though in classic architecture the cornice may occur also over the columns.

It is important that cornices, in common with all other projections from the face of masonry walls, should be throated on the largest vertical underneath face.

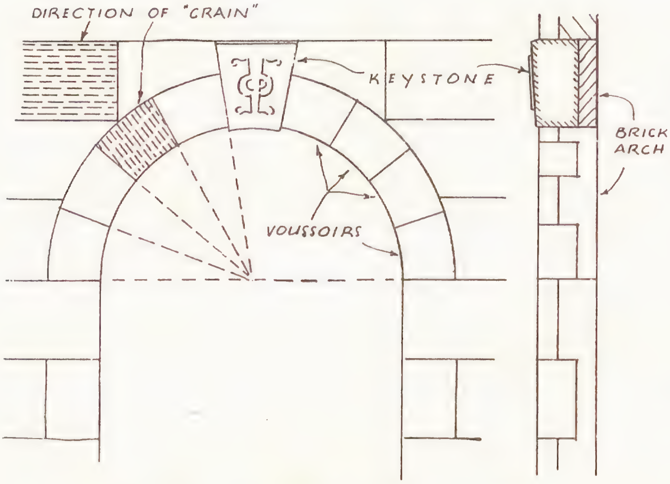


Fig. 186.—Semicircular arch with keystone.

The types of arches are the same as those described in bricklaying (see Chapter I, Vol. II), and are struck in the same manner. They consist of the semicircular, the segmental, the semi-elliptical, and the Gothic. Bastard arches are the rampant arch and the shouldered arch. In the pointed arch, the keystone is replaced by a joint on the centre line.

Oriel Windows are bay windows built projecting from an upper storey and supported on a series of corbellings or corbel courses. Each course projects beyond the one below, until the required projection for the bay window is reached. Oriel windows may be constructed on corbels or brackets, a flat base replacing the corbellings. They become then, by reason of their construction, more in the nature of cantilevers than what is rightly understood as oriels ; for though corbels or brackets are formed under them, the construction internally is of such a nature that the bay would, if required, be self-supporting. In fact, the brackets which give the appearance of supporting are often added after the bay is built. The actual support is given in such construction by steel joists cantilevered back into the building and bolted to a steel beam in the main wall and across the opening to the bay window.

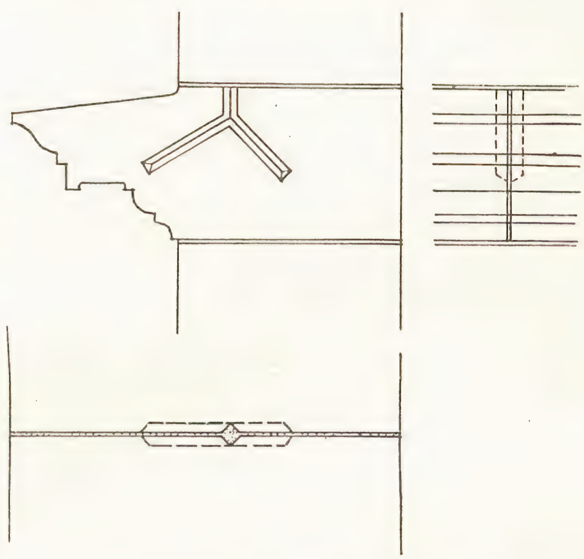


Fig. 187.—Cornice with cement joggle.

Sills are the stones, in one length, which form the bottoms of the opening

to windows. The bottom stone to door openings is often termed the sill, but wrongly so. This is properly named a *Threshold*.

In addition to forming the base of the opening, the purpose of the sill is to throw the rainwater caught by its horizontal face away from the walling below, and for this purpose it is sloped outwards on its upper surface, given a projection from the face of the wall and throated on its under surface. Where the stone is built into the jamb or side of the opening, it is squared to give a horizontal bed for the stone above it. This is termed a *Stooling*. As a preventive measure against rainwater being driven up by wind along the sill and under the wood sill, which rests on it, a weather bar is fixed to seal the joint, and to accommodate this a groove is cut along the upper face of the sill. This bar is bedded in red lead, and its upper half extends into another groove cut in the under surface of the wood sill. The sill is bedded where it projects into the jamb at its ends, but left free of mortar under the central part of its length. This is done to prevent the cracking of the sill at its centre if any settlement of the newly erected walling takes place, when undue pressure would be exerted upwards by the mortar under its centre. In stone walling the sill is built in as the work proceeds, but stone sills in brickwork are added after the wall is built, spaces being left for the sill ends, often filled temporarily with bricks set in sand. When the walling is being pointed, by which time any settlement should have taken place, the open joint should also be pointed.

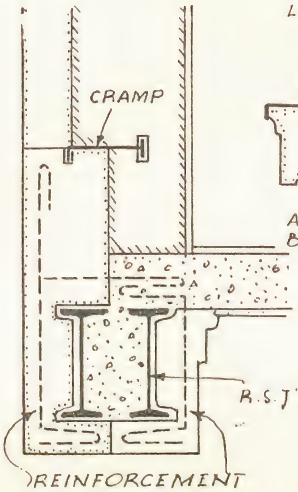


Fig. 188.—Beam casing in reinforced pre-cast stone.

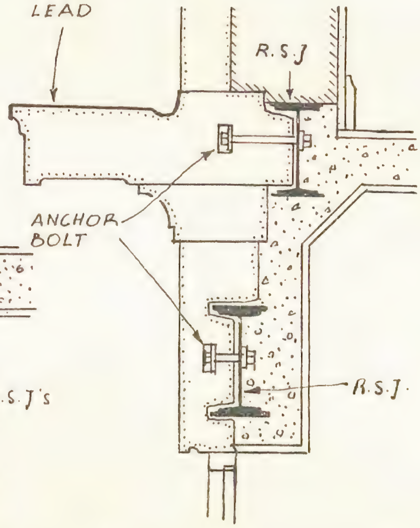


Fig. 189.—Cornice and entablature blocks anchored to R.SJ's.

The masonry at the side of a window opening is termed the *Jamb*. These jambs may be built of one stone, but are rarely so constructed, being formed either of quoins or with bonders in alternate courses, giving a long and short effect on the face. A *Rebate* is provided for the window frame to be fixed in. This is in the nature of a cheek or recess, and may be cut on the outside or on the inside of the jamb. The outside corner of a jamb is often moulded ; and if the moulding is a raised one, it may be finished on the sill, but if it is either cut away from the stone or the angle of the stone is splayed or chamfered, the bottom stone in the jamb is

furnished with a *jamb-stop*. This may be a splay mitred with the moulding, or a splay on the vertical corner, or it may be a mould cut in to fill the angle; the splay above stopping on the top of the moulding in the angle.

Hood Mould.—This is a moulding or drip sometimes fixed over a window head to throw off the rainwater. The method of finishing the

DIMENSIONS—"A" & "B" VARY IN ACCORDANCE WITH THE BRICKWORK GAUGE

Fig. 190.—Cast stone window frames. (Croft Granite, Brick & Concrete Co. Ltd.)

ends of this moulding is to return it downward vertically, or it may be terminated in a square set diagonally, or other geometrical decorative feature.

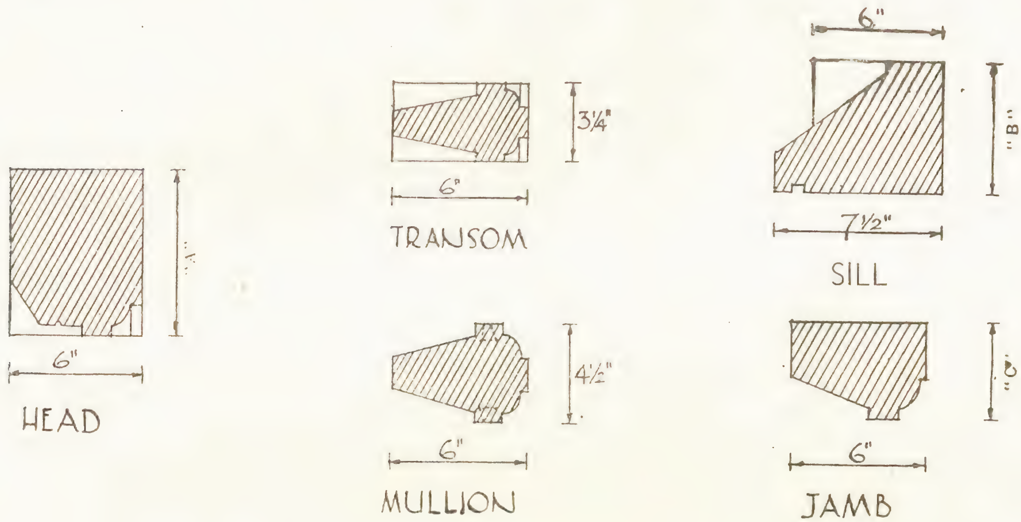
Wide windows are divided vertically by *mullions* which are formed of stones often of the same heights as those forming the jambs, and having the same detail and rebate as mentioned above.

Transom is the name given to the stone division of a window in its height. The detail of the top face of a transom is the same as that to a

sill; and along the under surface, a throating is cut, though the transom is not projected beyond the face of the mullions as a general rule.

The bottoms of mullions should finish on a seating cut on the sill and be jointed with a dowel mortised into the seating; and the mouldings, if any, may be finished in the same manner as described for the jambs. The transom is run across the window, if not too wide, in one stone, and is built into the jamb. The bottom stones of jambs are sometimes dowelled to the sills to prevent any lateral movement.

Cornices, as has been said, are projecting mouldings near the tops of walls. The stones are tailed into the walls, and it is customary to recommend that the stones composing a cornice should be set at right angles to the natural bed, but with the exception of strongly laminated



DIMENSIONS—"A" & "B" VARY IN ACCORDANCE WITH THE BRICKWORK GAUGE.
DIMENSIONS—"C" IS 4½" FOR STRAIGHT JAMBS, AND 4½", 6" & 7½" FOR BONDED JAMBS.

Fig. 191.—Details of window members.

stones it is preferable to set them in the same manner as in any other part of the building, *i.e.* parallel to their natural bed or current bedding plane.

The under surface of the greatest projection of the cornice should be throated, or it may be hollowed right back to the face of the next moulding below.

Small cornices may contain all the mouldings on one stone, but larger ones will require to be built up of several—and as, when there are several stones, the projection will produce considerable leverage, there should be a parapet, or at least a *blocking course*, built over the top of the cornice to weight the built-in ends down.

The upper surfaces of the cornice and blocking course should be weathered outwards, and the upper face of the cornice should be covered

with lead or asphalt. If the cornice is surmounted by a wall above, a trough should be cut near the base of the wall to conduct the water away to the rainwater downpipes. The lead must be bent down along the front edge of the top member of the cornice and turned up into a flashing groove, cut in the wall above. To fasten the edge of the lead so as to prevent the wind from raising it, lead dots should be run in to holes on the top. Asphalt is run on hot and keyed into a dovetailed groove.

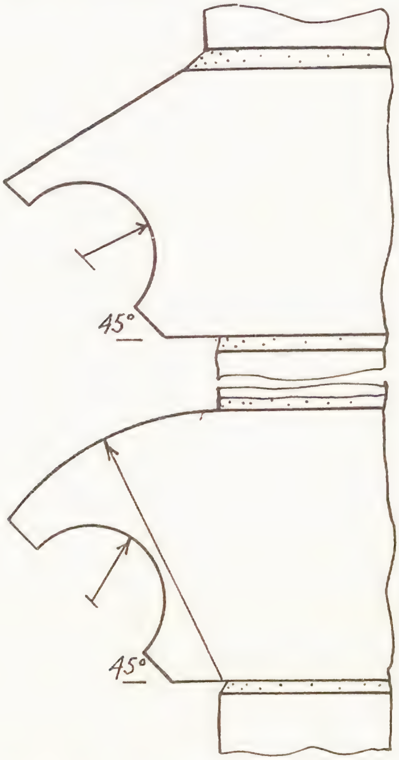


Fig. 192.—Sections through dripstone or label mouldings.

String Courses are horizontal bands, flush or projecting, of stonework. These may be plain faced or moulded, and are generally introduced either to mark the floor lines or to line with the heads or sills of windows. Any projection should be throated underneath, as already mentioned. Cornices and strings, besides being ornamental, assist in the bonding of the masonry, and in addition they afford a certain amount of protection to the face of the stonework.

Blocking Course is the term applied to the wall above a cornice so placed to weigh down, and so secure, the ends of the cornice stone. It may also serve as a parapet wall or as the base of a balustrade. The cramping of such stones should be very secure and run in with lead.

Eaves Course is a course of stone placed under an eaves where there is

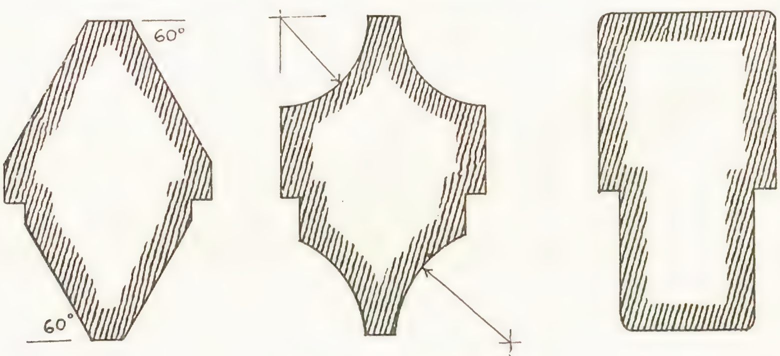


Fig. 193.—Mullions.

Splayed Cavetto. Square.

no coping, but an overhanging roof. These courses are both plain and moulded.

Parapet is a slender wall built above a cornice, partly for decoration purposes, and partly as a weight over the ends of the cornice stones. It may also serve as a protection to anyone working on the roof. It may consist of solid walling or be composed of piers and balusters.

Coping.—The coping is a covering to a wall to prevent the damp from penetrating. It is formed either flush or projecting, and if the latter, should be throated on the under and projecting surface. In addition to gable walls previously mentioned they are used on parapet walls. In any position it is advised that the coping should be weathered. Copings in sloping positions should be joggled and terminated with a skew back, and if long have one or two kneelers in their length. They are sometimes seated on *tile creasing* formed of a double course of plain tiles laid in and given a projection.

JOINTS

The following methods are employed in jointing and securing joints in stonework.

Butt Joint.—This is used when two faces are placed together, as, for example, in a flat arch. To give a binding between the two stones V joints are cut in the abutting face and cement is poured in. This method is also termed a cement joggle.

Dowelled Joint.—This method of assisting the stability of a joint is used to resist possibility of lateral displacement, as in the case of the base of a door or window jamb or mullion. Round holes are sunk in the jointed faces of both stones and a stout pin of metal or slate is fixed into the holes. Metal dowels, unless of a metal that will not rust, are not recommended, as they are the cause of splitting the stonework. Slate dowels are generally square in section.

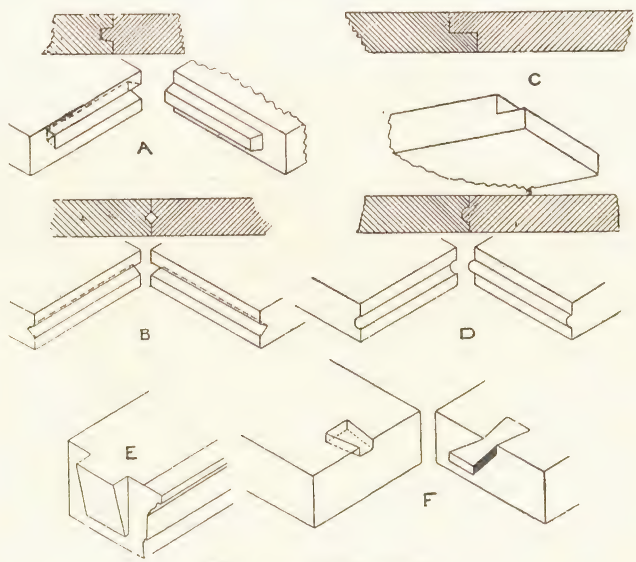


Fig. 194.—Joints used.
A.—Mortise and Tenon. **B.**—Butt. **C.**—Rebated. **D.**—Toggle. **E.**—Secret Key. **F.**—Cramp Mortise.

Cramps are also made in metal and slate. When of metal they should be run in and covered with cement. They are used for tying stones together to resist tensional stress, and by being let into mortises shaped

dovetail pattern, they tend to pull the stones together, or at least to resist any force tending to pull them apart.

Rebated Joints are also used in jointing arch stones in flat arches and for copings on gables. The rebate is formed on the jointed face generally at about half the depth of the arch stone, and the rebated face is parallel with the upper and lower face of the stones, whilst the abutting joint faces are cut in the direction of the centre of the arch.

A Secret Key Joint is also used in flat arches and lintels where it is desired to show a vertical joint on the face, but to have the major portion of the abutting faces as a radiating joint.

MORTARS

For *Rubble* walling where, as has been said, the mortar supplies the chief bond, a good mortar is required. This should be composed of 1 part Portland cement to 4 parts sand.

Mason's Putty is composed of 3 parts stone dust and 1 part lime putty. This is used for setting stones in wrought facing where the joints are required to be fine. The joints themselves are often grouted with neat Portland cement or with 3 parts of stone dust mixed with 1 part of Portland cement. For polished granite 2 parts sand to 1 part Portland cement is used; and for solid marble "Atlas White" is recommended.

Lime Mortar consists of 3 parts of clean sharp sand to 1 part of slaked lime, which may be blue lias lime, grey chalk, or stone lime, pure or white chalk lime. Slaked lime is lime which has powdered owing to exposure to the air or from the addition of water. Grey chalk lime is used in the proportion of 1 part of lime to 3 parts of sand. Pure lime is used in the proportion of 1 of lime to $3\frac{1}{2}$ of sand.

Lime Putty consists of a mixture of *Fat lime* and 3 parts by weight of water. Fat lime is derived from white chalk and forms a paste when mixed with water. It is pure white, rapid-slaking, slow-setting, and non-hydraulic.

It is a mistake to use a strong cement mortar, except where an exceptionally strong, dense stone is used. For ordinary load-bearing masonry mix No. 3 specified below is quite strong enough. The two weaker mixes are of adequate strength for ashlar and facing work.

The three mason's mortars following have been favourably mentioned by the Building Research Station:

(1) 16 parts fine crushed stone (by volume), 4 parts lime putty or hydrated lime, 1 part Portland cement.

(2) 12 parts fine crushed stone (by volume), 3 parts lime putty or hydrated lime, 1 part Portland cement.

(3) 7 parts fine crushed stone (by volume), 5 parts lime putty, 2 parts Portland cement.

STONE STAIRS

Stairs built of stone are not so frequently used in domestic buildings as in the past, having been replaced by concrete and metal. Where used they consist of either of two kinds : solid or slab.

Solid Steps are cut from the solid stone, and are either rectangular or spandrel in shape. A spandrel step is triangular in section, the under-

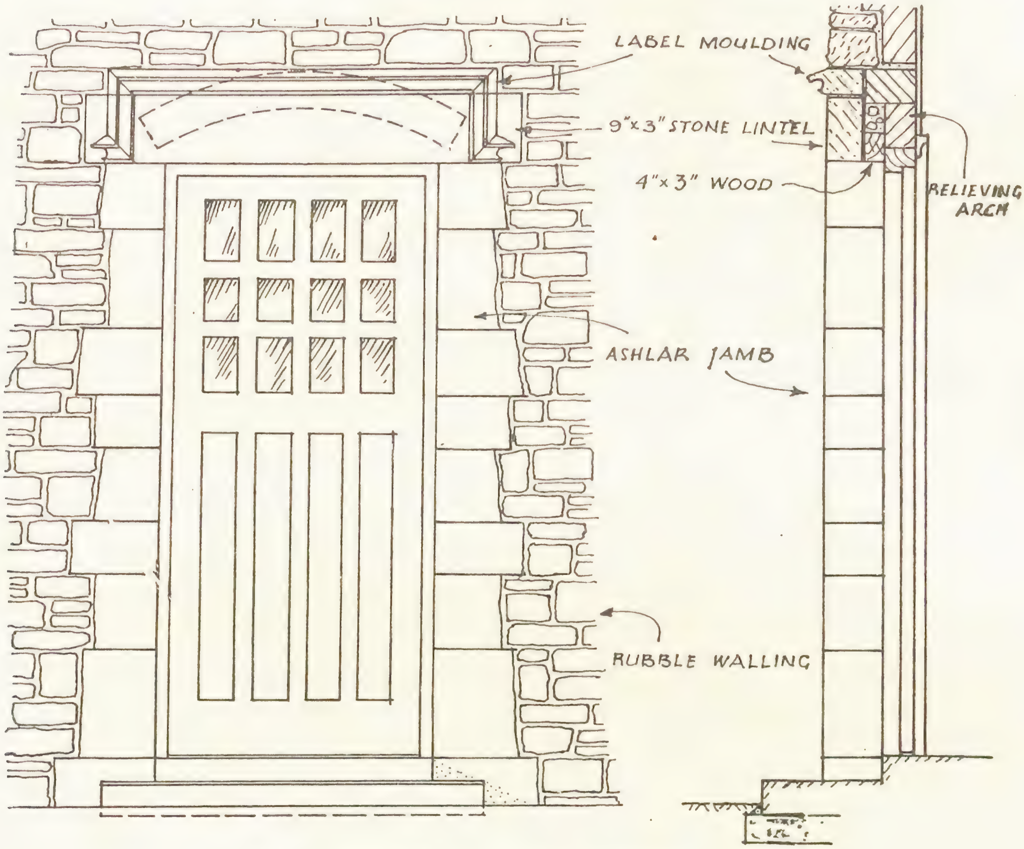


Fig. 195.—Doorway in rubble wall with squared jambs.

neath corner being cut away to afford additional head-room, while also making the step lighter.

The stones used in constructing solid steps are worked on the tread and the rise, and when used externally the treads should be slightly weathered. The nosing may be rounded or moulded or left square. They are jointed sometimes with a rebate joint and sometimes with a splayed joint at the junction of the tread and riser faces.

Spandrel steps are also termed *Feather-edged Steps.*

Stone stairs constructed of thin slabs are not often seen, and their construction is similar to that of wood stairs. Such stairs are sometimes

used out-of-doors, and constructed of slate slabs, when they are in the nature of open steps consisting of treads only in slate supported on metal strings.

Solid Stairs are supported either by being built into walls at both ends or built into a wall at one end, the other end being supported by a wall underneath which rises no higher than the underside of the step. Where it is required to make such a wall economical, or to admit light and air, it is composed of piers and arches, and in such conditions the rampant arch is employed.

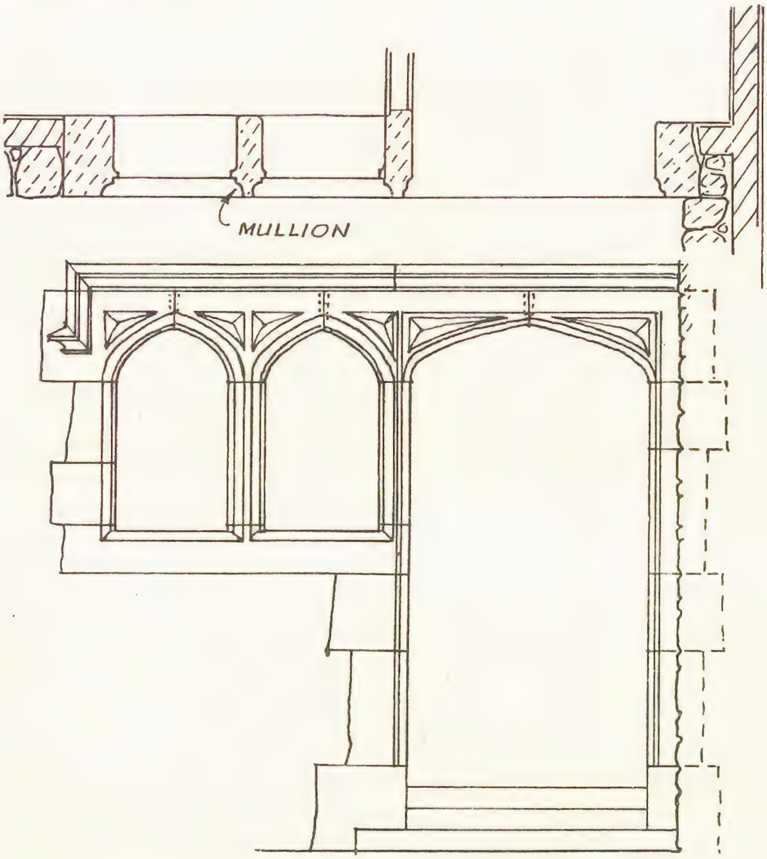


Fig. 196.—Doorway and hall lights with 4-centred heads.

Stairs supported at one end only may depend almost entirely upon the cantilever afforded by the wall into which they are built, and partly also on the support which each step affords the one above it at its joint between tread and riser.

When the steps are built in at both ends they require to be cut 12 inches longer than the width of the staircase, so that at least 6 inches may rest on each wall ; but in cases where the walls do not rise above the steps the length will require to be the width of the staircase plus the thickness of the walls.

The bottom step of solid stairs should be sunk into the floor to increase the rigidity of the flight by preventing any tendency to slip. Hanging steps, *i.e.* those built in at one end only, must be set in cement, and let into the wall for a distance of at least 9 inches.

Types of Stairs.—*Straight Stairs* are those which rise from floor to floor in one flight, and are generally formed of solid or spandrel steps built in at both ends; or they may be formed of hanging steps.

Dog-legged Stairs consist of two or more flights, the outer ends of the steps of each upper flight ending over those of the flight below. They are formed of hanging steps, one end only being built into the wall. At the junction of the flight there may be a landing known as a *Half space Landing,* which is one that extends level across the whole width of the staircase; or if it is required that the flight should rise more quickly the space may contain *Winders.* These are steps triangular in plan, which afford a means of rising more quickly with less expenditure of space.

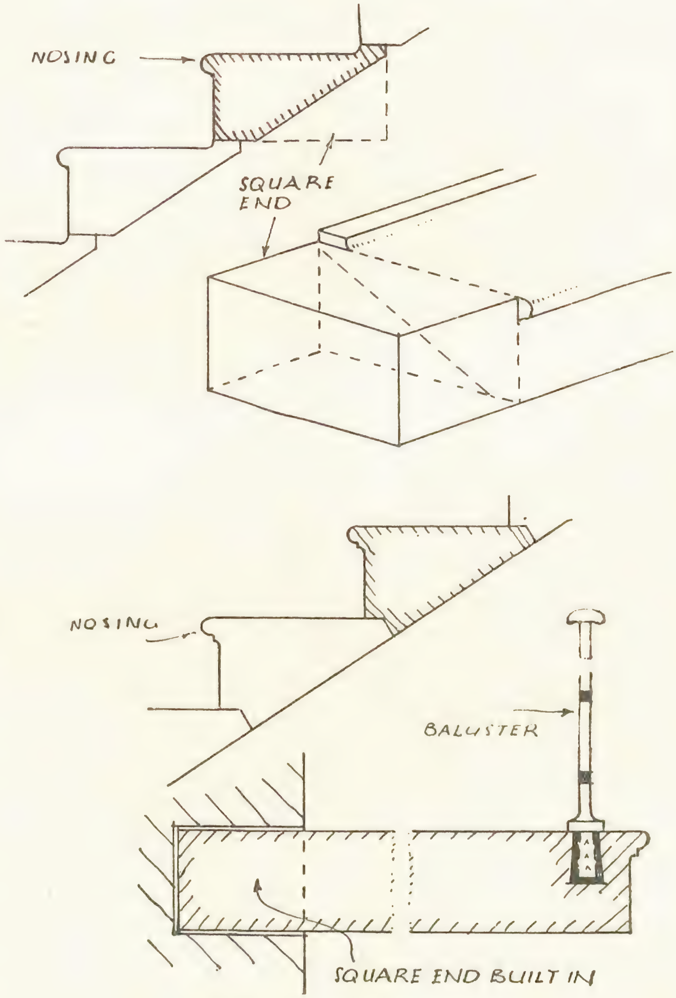


Fig. 197.—Stone stairs.

Geometrical Stairs consist of hanging steps having no support at the outer end except that afforded by the junction of the tread and riser. The stair is continuous from bottom to top, both handrail and string being continuous also. They may be in plan either rectangular, polygonal, circular or elliptical, and they will have no landings, this space being filled with winders.

In between the ends of the steps there will be an open well which

requires more or less space, but this is a wise expenditure, as it permits of the winders having more breadth of tread at their narrowest part, *i.e.* against the well hole.

Geometrical, Circular Stairs are those in which the steps of spandrel section are built into the wall at one end only, the other end being left open to form a central open well. The handrail is continuous and the steps all winders.

Circular Stairs are of two kinds: (1) *supported at both ends*—one end being built into the wall and the other either built into a hollow newel formed of brickwork; or at the end of each step there may be a circular block which, when rested on the one below, goes to build up a circular central newel. Such stairs are used in church towers. (2) *Hanging steps*—which are constructed as described above for Geometrical Circular Stairs.

HOISTING AND SETTING

The use of masonry in the construction of a building necessitates the employment of a heavier form of scaffolding and certain types of lifting

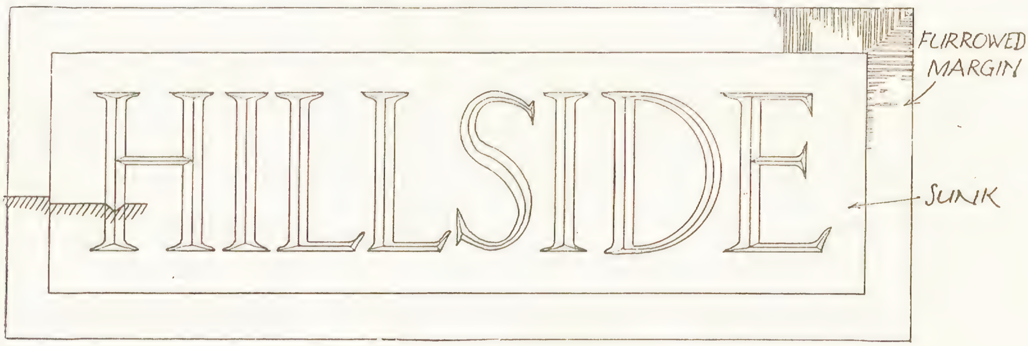


Fig. 198.—Lettering incised in stone.

gear and tackle of a stronger nature than that used on brickwork jobs. This is, of course, occasioned by the greater weight and size of the stone blocks.

The Scaffolding, instead of having support from the wall of the building, is carried by a second series of standards and ledgers against, but independent of, the wall.

In modern steel buildings a good deal of the masonry construction is carried out from within the building, access to the outside being obtained by the use of hanging scaffolding.

The mason's scaffold is now to be obtained formed of steel tubes as well as of timber, the principles of its construction, so far as the various members forming it, being the same as those applying to the wood scaffold.

Very heavy construction requires that the scaffold, in its lower part at

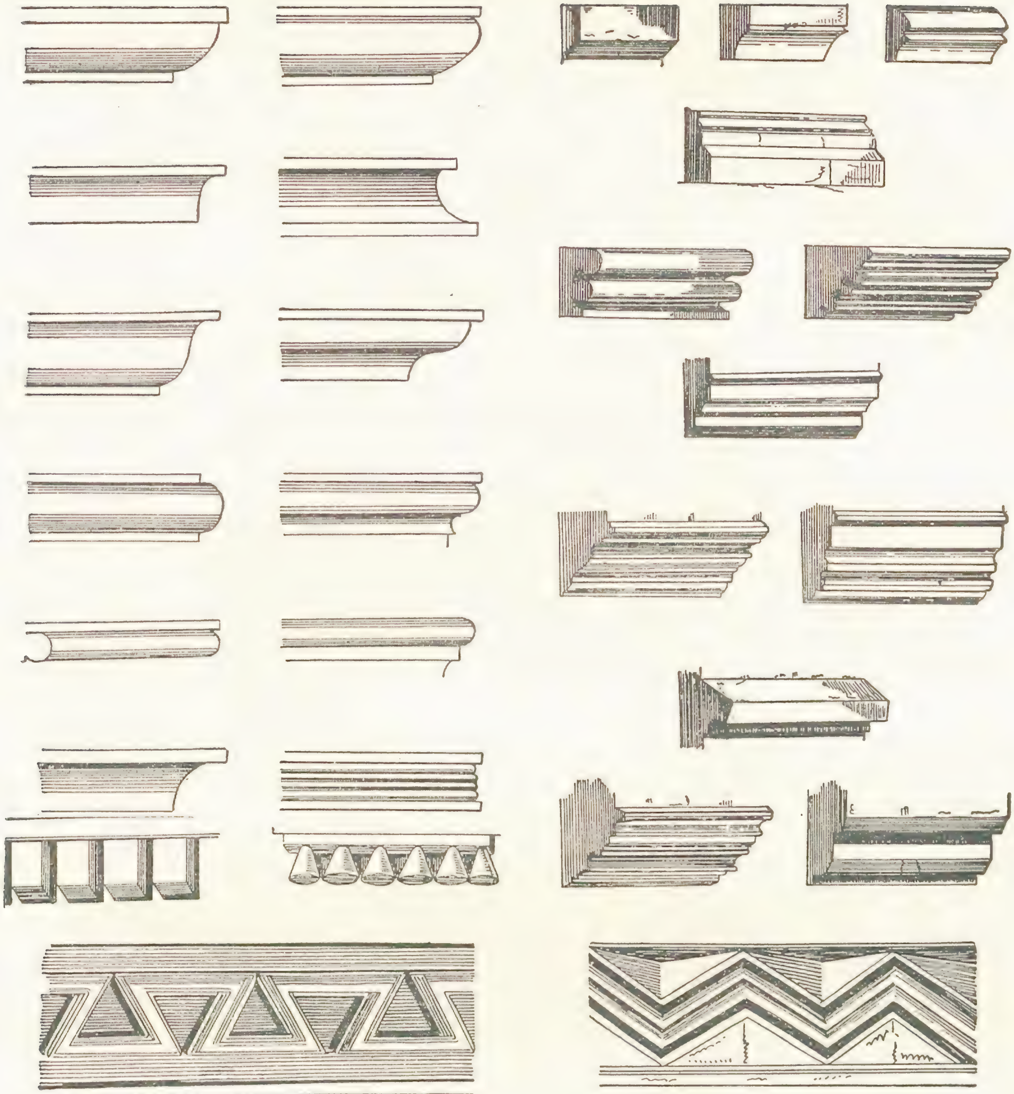


Fig. 199.—Mouldings.

Roman and Greek.

Ovolo or Echinus.
Apophyges.
Cyma Recta.
Torus.
Bead.
Cavetto.
Dentil.
Quirked Ovolo.
Scotia or Trochilas.
Cyma Reversa or Ogee.
Quirked Ogee.
Astragal
Reeds.
Guttæ.

Norman.

Dovetail.

Norman and Gothic.

Early Abacus.
Late Abacus.
Late Abacus.
Basement, Early.
Gothic.
Early English Abacus.
Early English Architrave.
Late English Architraves (1 and 2).
Perpendicular Basement.
Perpendicular Architraves (1 and 2).
Norman Chevron.

least, should be constructed of squared baulk timbers, when they become in the nature of *Gantries*. Such a construction, if sufficiently stout, forms a convenient platform for the storage of masonry until wanted, and affords space for a kind of workshop on the job for the mason to do any cutting to fit.

For the construction of extra-heavy masonry walls, more for engineering than for building purposes, where the blocks of stones are too heavy to be handled by the usual means, the gantry carries a *Traveller*, which runs on rails extending across the gantry at right angles, the wall to be built being situated between the inner and outer portions of the gantry.

The Cantilever Scaffolding is used for masonry construction as for brickwork, where it is required to leave the space at the base of the wall free for traffic.

Methods of Lifting.—Handling stone being a heavier job than any required by brickwork, special hoists are required. On steel-frame buildings the same cranes used to raise the steelwork will be employed, the stone being lifted from the lorry in which it is delivered, and if ready for use deposited where it is required to be built in, all in one operation, by which much time is saved.

Where cranes are not used a *Mason's Hoist* is fixed to scaffolding above the wall. This consists of a chain tackle with pulleys at either end attached to hooks, the upper one being suspended from a ledger above the work, known as the *Head Tree*, and the lower one being passed through the eye of the *Lewis Bolt* or other appliance which is fixed into a hole in the block of stone to be raised and deposited.

The Appliances for Lifting Stone consist of various forms of Lewis bolt and combinations of dogs, claws, and chains.

Chains.—An old-fashioned method, not now much used since the passing of the Home Office Scaffolding Regulations, is that of passing a chain round the stone, and through a ring in such a manner that as soon as the crane takes the weight, the chain tightens. At best, this method is only suitable for rough stone, as finished stones would be marked and broken by a chain. The removal of the chain also necessitates a certain amount of waste time in wedging up the stone, and later in the removal of the wedges.

Dogs, or steel hooks fitted with rings through which a chain passes to a central ring, are used for lifting jointed stones and rough blocks. But as the use of these requires holes to be cut in the side faces of the stone for the hooks to obtain a grip, they are not so satisfactory as the—

Lewis Bolt.—A Lewis bolt, formed of separate pieces, is termed a three-legged Lewis. This consists of a shackle and a removable pin attaching the shackle to the three legs, the two outer ones of which are of wedge shape, the narrower part of the wedge being at the top. In between this is a rectangular piece of steel of equal width at either end. A mortise is cut in the stone of a dovetail section, being wider at the bottom than the top, the width of this at the top being just sufficient to

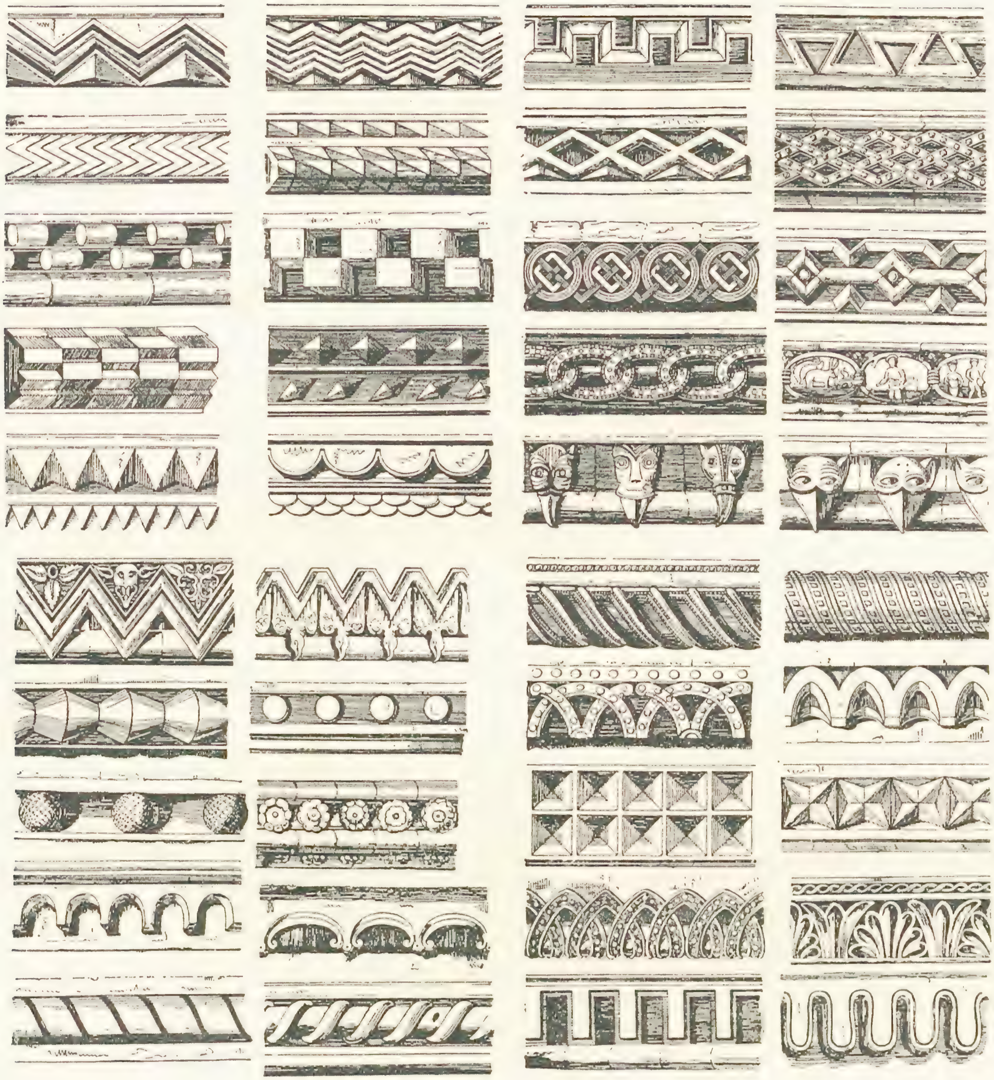


Fig. 200.—Norman Mouldings.

Chevron or Zigzag.
Reversed Chevron.
Roll Billets.
Prismatic Billet.
Indented.
Ornamented Zigzag.
Double Cone.
Fir Cone.
Circular Arched.
Cable.

Multiple Chevron
Saw Tooth.
Square Billet.
Nail Head.
Scalloped.
Bird's Beak
Pellet.
Rose.
Elliptical Arched.
Twining Stem

Embattled.
Lozenge.
Reticulated.
Chain.
Beak Head.
Beaded and Twisted Panel.
Interrupted Arched.
Hollow Square.
Open Heart.
Label Corbel.

Dovetailed.
Studded Trellis.
Diamond Fret.
Medallion.
Cat's Head.
Billeted Cable
Pointed Arched.
Star.
Braided Border with Honeysuckle.
Nebuly.

allow the two outer legs without the centre leg to pass into the mortise. When these are in position, the width of the dovetail and the wedged shape of the outer legs allow of their being separated sufficiently for the middle leg to be inserted between them. The shackle is then placed in position, and the pin passed through it and the holes in the tops of the three legs. As soon as the crane takes the weight of the stone, the wedge formed by the three legs fits tightly in the dovetailed mortise, from which it can work free only by the fracture of the stone. To release the Lewis bolt the pin is knocked out and the shackle and central leg removed, when the wedge-shaped legs will pass the narrow part of the dovetail.

Chain Lewises are formed of three rings with two legs attached curving outwards. The centre ring is larger than the other two attached to it, and the result of the strain on the hoisting chain is that the two smaller rings are pulled towards each other in their attempt to get to the bottom of the large ring. This results in the pulling of the heads of the curved legs together, and as these legs work back to back and are bent outwards the natural result is that the lower part of the legs are pushed outwards, and these, when placed in a dovetailed mortise, grip the inclined faces of the mortise.

CHAPTER 13

MORTARS

THE mortars used for jointing brickwork and stonework consist of a mixture of lime, or cement, sand, and water. There are three kinds of mortars in general use: (1) lime mortar, (2) lime-cement mortar, (3) cement mortar.

Mortar consists essentially of an aggregate, generally sand, bound together with a cementing material (lime or Portland cement, or aluminous cement). In a well-mixed mortar each grain of aggregate is surrounded by a film of cementing material. The functions of the mortar are to hold the bricks or stone blocks together by adhesion, to prevent water entering between the bricks, and to give the wall adequate strength and durability. Generally, it is advisable to use a mortar of similar strength and porosity to the brick or stone. Thus, a strong cement mortar should not be used with a porous brick or stone of only moderate strength.

MATERIALS

Limes.—Lime is manufactured by burning or calcining limestone and other rocks which consist chiefly of calcium carbonate, the process yielding calcium oxide, usually called quicklime. This material readily combines with water, considerable heat and expansion occurring in the process. The result is slaked or hydrated lime.

There are various kinds of lime, each requiring different treatment. The manufacturer's instructions should be carefully followed in slaking and mixing.

Limes may be divided into three types: (1) non-hydraulic, (2) moderately hydraulic, (3) strongly hydraulic.

The " hydraulic " property of a lime is its capacity for setting and hardening in the presence of water. This is similar to the setting and hardening property of Portland cement, except that with lime it is not so strong.

Lime Mortars.—Lime mortars are usually prepared in the following proportions: one part lime to three parts sand, by volume.

For hand-mixing the sand is placed in the shape of a ring on a clean, watertight platform. The lime is placed in the centre, water is added, and the heap left to slake for about twelve hours. Thorough slaking is essential, otherwise the lime will expand and " blow " in the mortar joints.

After mixing, the heap should be smoothed over the exterior with the

spade, so that air cannot readily penetrate the interior. Non-hydraulic lime mortar so treated will keep in good condition for a period up to seven days. It should be knocked up as necessary to bring it to a suitable plastic condition. Non-hydraulic lime mortar is not recommended for permanent walls, as it has little strength.

Moderately hydraulic lime mortar should be used if possible on the day of mixing, or within twenty-four hours at the outside. If allowed to stand longer, the setting and hardening action will take place in the heap, and much of it will be lost when the mortar is used.

Strongly hydraulic lime mortar, such as a mortar made with blue lias lime, has a strong setting and hardening property. It makes a durable mortar if properly prepared, but must be used within a few hours of mixing. If allowed to stand for long, the setting action takes place before the mortar is used. The manufacturer's instructions should be carefully followed. Ground hydraulic limes should be slaked by mixing with damp sand to make a stiff mix. The finished mix is then prepared by adding further sand and water. The mortar should then be used within about four hours. Any mortar left after standing for half a day should be rejected.

Mill Mixing.—On large jobs mill mixing is usual. It is efficient, especially in breaking up the small lumps to a fine powder. Furnace ashes, clinker, and crushed bricks are often used as aggregate instead of sand. Ashes and clinker make a black mortar of good strength, provided that the aggregate is free from partially burnt material and chemical impurities. If crushed brick is used, the old bricks must be clean and old mortar or plaster cleaned off.

The Mixing Operation is carried out either in a pit or on a close-boarded platform of wood. The sand and lime are measured into the correct amounts to give the required proportion, and the sand is formed into a circular bank on the platform. The lime is then placed within this bank, or ring, and water is sprinkled on with a hose-pipe, which is best suited to the purpose when fitted with a rose or some form of sprinkler. Steam will be generated during this sprinkling operation, and when this has ceased, the lime is stirred with a " larry," which is a kind of long-handled hoe. The sand is then shovelled, starting from the outside of the ring first, on to the lime, the larrying operation being continued the while. When thoroughly mixed the mortar is left to stand for a week or so before being used, when it should be " buffered," or beaten up again with the larry and shovel. For use, it is customary to add more water, as the wetter it is, up to a point, the easier it is to handle, but this should not be overdone. When required for use with non-absorbent bricks or stone, it should be used as dry as possible. For absorbent bricks or stone it may have an increased quantity of water to allow for the absorptive properties of those materials.

It should be remembered that the setting action of mortar consists in the action which takes place in the lime. This action is the absorption

by the lime of CO_2 (carbon dioxide) to form a crystalline carbonate of lime. This calcium carbonate forms an impervious skin on the surface. This prevents the further entrance of CO_2, which, it may be noted, it is the function of the sand to facilitate, as sand retards the formation of this external skin and renders the mortar more absorptive, thus allowing the CO_2 to penetrate further and for a longer time. Consequently, as the setting operation is prolonged, the damper the material and the thicker the walling, the slower will be the drying, and the mortar will not attain its full strength until dry and set. Thus, fat limes should be mixed with plenty of sand to enable the CO_2 to penetrate.

Burning.—To prepare the lime for use in mortar, it is burnt or calcinated, and the operation requires experience to ensure that the proper heat is maintained and the lime burned to the degree required.

Underburnt lime will be likely to contain uncalcined limestone, which will not slake properly with water.

Overburning also causes a lime very difficult to slake, with the result that the unslaked particles will slake later when incorporated.

The purpose of this burning operation is to render the limestone suitable for combination with carbonic-acid gas, as $CaCO_3$ (lime) is insoluble in water, but is rendered soluble by calcination (burning), which drives off the CO_2 (carbon dioxide), leaving calcium oxide, CaO, in the mortar, which, if unslaked, causes it to " blow."

Correct Burning should cause the lime to change in colour from red to white.

Lime is burnt in kilns of two kinds : the *Flare* and the *Tunnel.* They may be intermittent or continuous in working.

The Flare type of kiln is generally built of brick, though sometimes it is of stone in a cylindrical shape, and generally tapering towards the top, near which the loading door is situated.

The kilns are usually built in series, and they are situated in the quarry from which the limestone is excavated close up against the rock face, so that the loading door may be reached from the upper ground and access gained to the unloading door on the other side from the lower ground. The conical-shaped top is more economical of fuel, and it is left open as a flue to conduct away the products of combustion. The fire is situated at the bottom of this kiln under fire bars extending across the two fire channels. Over these bars rough arches of limestone are built to provide additional draft, and the kiln is then filled from the loading door above with the limestone to be burnt. In some kilns the domed top is replaced by a rough shed.

The heat must be applied gradually and continued for about seven days, when the limestone should be satisfactorily calcined. Too rapid burning crumbles the stone away to dust. It is important that the stone should be withdrawn from the kiln as soon as all the carbon dioxide has been driven off. This condition is reached when all the redness has disappeared and the colour of the burning stone changes to a brilliant white

glow. At this point the stone should be at once withdrawn, for, as has been said, overburning produces over-calcination, the result being a lime which is very difficult to slake. Delayed slaking action, taking place after the mortar has been built in, causes it to blow, which in brick or masonry results in decay at the joints, and in plaster, in blisters or popping (pinholes).

Slaking.—The next operation consists in the addition of water, and is known as *Slacking* or *Slaking*. This is attended by a great hissing and cracking of the stones, leaving behind a white powder which is calcium hydrate. The chemistry of slaking is that, when treated with water in this way, it will then combine readily with CO_2 to form crystals of calcium carbonate, which is the strength of mortar. The soluble lime in a saturated solution is ready for the absorption of CO_2.

It is essential that the slaking operation should be thorough, as any unslaked lime in mortar will have similarly disastrous results to those arising from an overburnt lime. This is the reason underlying the practice of leaving mortar to stand after it has been mixed.

The Setting of Lime.—Fat limes set by the absorption of CO_2 from the atmosphere by the particles of slaked lime in the mortar—chemically this action is expressed as follows:

$$Ca(OH)_2 + CO_2 = CaCO_3 + H_2O.$$

The $Ca(OH)_2$ forms an impervious skin with a tendency to form on and adhere to anything of a rough, hard nature. Without the addition of sand, or if the sand were not present in a sufficient proportion, these crystals would form on the brickwork or masonry, and so produce an impervious skin round the mortar, preventing it from setting in its interior. Consequently, to provide the necessary rough matter throughout the body of mortar, sand is mixed. The addition of sand, also, of course, increases the bulk, and whilst the strongest mortar would consist of lime and sand in the proportion of 1 to 1, a more economical and sufficiently strong mix is to be obtained from a 1 to 3 proportion.

Hydraulic Limes set by an integral crystallisation as well as by CO_2 absorption. The crystals are of hydrated calcium silicate. Consequently, depending, like cement, on crystallisation for its set, it is possible to use hydraulic lime in the centre of very thick masonry as well as under water.

Hydralime is made from quicklime and water in the requisite proportions. It is supplied grey for mortar and white for plaster, and where rapid setting is required, Portland cement is mixed with it in the proportion of hydralime 2 parts, Portland cement 1 part, and sand 8 parts. For ordinary plaster work it is mixed in the proportion of 1 part hydralime to 4 parts sand.

Blue Lias Lime is one of the best hydraulic limes, and is obtained near Lyme Regis in Dorsetshire. This contains 20 per cent. of clay, and it is due to the presence of the clay that the silicates and aluminates of lime are

formed during calcining. These, in combination with the water used in slaking, form the hydrated silicate and aluminate crystals which assist in the setting as explained.

Gypsum is the stone from which *Plaster of Paris* is made by heating in two ways: (1) by boiling; and (2) by baking. The name "plaster of Paris" originates from the fact that gypsum was first quarried near Paris. It is found in this country in the northern counties, including Derbyshire and Cheshire, and the finest deposits in the world are said to be those of Canada.

The Boiling Process is carried out as follows. After being quarried the gypsum is broken up by means of a pulveriser and ground between millstones. It is then placed in a large open boiler and left for three hours, when the water of hydration having been driven out, it becomes a dense heavy powder which, on being cooled, is ready for use. Boiled plaster of Paris is more reliable than baked.

The Baking Process is carried out in a flat kiln or oven, which is heated to a red glow, and the gypsum then thrown in. After about twenty hours the gypsum is removed and ground. It is more important that the process should be gradual, and continued for a time sufficiently long to drive out the water of hydration, than that the heat should be great, for then it will be turned into a material quite useless for plaster.

Plaster of Paris is used mainly for ornamental plaster and for domed ceilings in plaster. It cannot be used out of doors, as it has no resistance to the weather. It sets, on being mixed with water, by solidification, and the best plaster when set is almost white. Pink plaster is used for making casts and models. It is sometimes mixed with ordinary lime to slow down the slaking and to increase the setting powers.

Selenitic Lime is a scientific combination of lias lime and magnesian limestone and plaster of Paris. It is quick setting, and the proportion of sand can be increased by its use.

For use as a mortar the following method is advised by the manufacturers:

Into the pan of a mortar mill pour 4 full-sized pails of water and gradually add 2 bushels of selenitic lime—grind to the consistency of a creamy paste. Then throw into the pan 10 bushels of clean sharp sand, burnt clay, or broken bricks. Grind till thoroughly incorporated.

In a plasterer's tub the mortar may be prepared by adding to 4 pailfuls of water 2 bushels of selenitic lime, and keeping it well stirred until it becomes a creamy paste. Make a ring of 10 bushels of sand, and pour the selenitic paste through a $\frac{1}{4}$-inch mesh sieve, adding water as required. Turn over and mix with the larry.

Lime Putty is run into a box, or a pit lined with plaster, and then left to stand for at least three months. In preparing this, the lime is slaked in a similar manner to that employed in preparing coarse stuff for plaster, and then the paste is run through a sieve. The water should be drained

off after it is run into the tub or pit, and the putty should be covered up from the air or it will lose its setting properties. This is often done by spreading sacking over the pit, but the practice is rather wasteful, as the top layer will be found dry, short, scaly, and inert when required.

Puzzuolana is a volcanic substance which, when mixed with lias limes, produces a useful mortar though inferior to that made from Portland cement.

Roman Cement is prepared from London clay by burning the nodules at a low temperature. The nodules consist of a dark-coloured argillaceous limestone found in the Isle of Sheppey. As it is much weaker than Portland cement, it is not suitable for use in proportions over 1 to 1. It sets in about fifteen minutes after mixing, and consequently is used mostly for works, such as tidal constructional work, only exposed for certain hours at a time. It is now rarely used.

Martin's Cement is a white cement having a gypsum basis. It is of a creamy colour and sets very hard, and is used as a hard wall plaster.

Medina Cement is similar to Roman but lighter in colour.

Parian Cement is a refined and processed form of plaster of Paris which gives a fine surface. It is used on a backing of Portland cement.

Robinson's Cement also has a basis of gypsum, and is used mixed with sand, with which it must be mixed dry and wetted just before use. It is useful for cornices and castings, and walls on which it is used must be well wetted first. It is non-absorbent, and so is very suitable for repair jobs, as it can be painted or papered over soon after setting.

Sirapite is another plaster which has a gypsum basis, and is also termed a hard wall plaster, used much in hospitals and other public buildings where sanitary walls are essential. It is gauged with sand and water, and its cost is about equal to that of ordinary plaster. Two coats only are required. On brickwork the proportions are 3 of sand to 1 of sirapite, and on lathwork, 2 parts sirapite to 1 of sand. It is suitable for use on metal lathing, being entirely free from any acid—it should not, however, be used in damp situations.

PORTLAND CEMENT MORTARS

Portland Cement.—This cement is made from a chalk and clay slurry which is processed, dried, and then calcined in a kiln. The manufacture is described in Chapter 6, Vol. II.

Portland cement when mixed with water develops strong setting and hardening properties. The setting action is divided into two periods: the initial set which occurs in about thirty minutes from the time water is added; and the final set which occurs in not more than ten hours. Thereafter, the cement steadily hardens, attaining approximately 75 per cent. of its final strength in seven days.

It is most important to use a Portland cement mix before the initial set occurs—within about twenty minutes. If the cement mix is disturbed after the initial set, its strength will be seriously impaired.

The setting action will continue under water, though flowing or falling water will wash away the mix. Work should, therefore, be protected from heavy rain.

Portland cement must be kept dry until mixed. It should be stored in a dry, airy shed, on a wood platform raised above the floor. It may be stored in the open for two or three days if placed on a dry wood platform and covered with tarpaulin.

The cement should be a fine powder. The presence of hard lumps is a sign of deterioration. The cement should be warm. The temperature varies, but cold cement should not be used until it has been scientifically tested. Ordinary Portland cement should be certified by the manufacturer to comply with British Standard Specification No. 12.

Portland Blast-furnace Cement is made from blast-furnace slag, which contains silica and alumina—the chemicals which cause cement to set and harden. This cement is made according to a special British Standard Specification, and it has the properties of ordinary Portland cement.

Rapid-hardening Cement is a special kind of Portland cement. Although the setting period is similar, rapid-hardening cement reaches in four days the strength which ordinary Portland cement reaches in twenty-eight days, and its ultimate strength is greater than that of the ordinary cement. It is useful for work which must be completed within a minimum period or loaded at an early date.

High Alumina Cement is both rapid hardening and quick setting. Its principal compound is calcium aluminate, which gives this cement its characteristic advantages. A curious feature is that the period of initial set is three and a half hours (for ordinary Portland cement it is half an hour), but the final set takes place in four to five hours. The longer time taken for the initial set is an advantage, as it extends the period in which the mix may be used. Another advantage is that high alumina cement is not affected by certain substances which tend to decompose ordinary Portland cement.

Cement Mortars.—The proportions vary according to the strength desired. The following is of adequate strength for all ordinary purposes: one part Portland cement to three parts sand, by volume.

There are disadvantages in a stronger mix. The stronger the mix in Portland cement the greater the shrinkage. This may result in crazing and the development of fine shrinkage cracks between mortar and brick or block. For this reason brickwork in a strong cement mortar sometimes admits damp, though the bricks may be hard and dense.

The sand and cement should be measured, using the measuring-box described in Chapter 7, Vol. II. The sand is measured first on a dry

platform. The bottomless measuring-box is then placed on top and the cement is measured. The two materials are then thoroughly mixed in the dry state. Water is then added gradually through a fine rose, and the mix is thoroughly worked with the spade to make a mortar just plastic enough for easy working. The mortar should be protected from hot sun rays. It should be used within about twenty minutes of mixing.

Grout.—This is cement mortar mixed with plenty of water to bring it to a semi-liquid. It is poured into interior joints in thick walls, and also in repairing old work. But as far as possible all joints should be filled with ordinary mortar as the bricks or stone blocks are laid.

Lime-cement Mortar.—This is sometimes called "compo" or "gauged" mortar. It combines the advantages of lime and cement mortars, and for all ordinary work it is preferable to either. Setting and hardening of compo is superior to lime mortar, and, though the strength is not so great as cement mortar, it is adequate for walls and piers bearing normal loads. A great merit of lime-cement mortar is that it is not likely to develop shrinkage cracks. It works easily off the trowel, and sound work can be done at a higher speed than with cement mortar.

It is advisable to use a non-hydraulic lime for compo, the Portland cement providing the setting and hardening properties. The Building Research Station recommends that at least 20 per cent. of the total volume of lime-cement should be cement.

The following proportions make a fairly strong mortar : 1 part Portland cement, 1 part non-hydraulic lime, 4 parts sand.

If the lime-sand coarse stuff is prepared first, one part of cement, by volume, should be added immediately before use to make a 1 : 1 : 4 mix. This is usually the most convenient method ; but the mix may be prepared with dry hydrated lime, cement and sand. However the mix is prepared, the mortar should be used within three hours of adding the cement. Retempering by adding water after the mortar has stood for some hours has a weakening effect, though retempering within twelve hours, using the minimum amount of water, is permissible where maximum strength is not important. High alumina cement is not suitable for lime-cement mortar.

Sand.—Any clean sand is suitable for making mortar. It is desirable to use "graded" sand, by which is meant a mixture of sand particles from small to large. If most of the particles are large, the mortar will be harsh and will not work easily off the trowel. If very fine sand is used, more water is necessary, resulting in excessive shrinkage and some loss of strength.

Coloured Mortars.—Mortars may be coloured by the addition of certain vegetable or mineral colouring materials during mixing. They are used for pointing.

Black Mortar may be obtained by adding 2 per cent. of carbon-black or lamp-black. If *Grey* is desired, the quantity should be reduced.

Buff Mortars are obtained by the use of 10–15 per cent. yellow ochre.

Red Mortar.—Iron oxide, 10 per cent.

Blue Mortar.—Ultramarine, 5–7½ per cent.

The pigments should be made into a smooth paste and mixed with the lime just before use, the lime having been slacked at least three days previously.

Sands of light colour, such as Leighton Buzzard sand, are also used to make pointing mortar.

Special colouring pigments, and dry mixes to which water only is added, are now obtainable.

CHAPTER 14

BUILDING MATERIALS

In this chapter building materials are briefly described in alphabetical order. Further descriptions of the leading materials, such as brick and timber, are given throughout this work.

The list of British Standard Specifications printed as an Appendix to Volume IV should also be consulted.

Acid.—A chemical compound of hydrogen and other elements. Acid solutions have a sour taste—vinegar for example—and strong acids burn the skin. Acids present in heavily polluted atmosphere attack certain building materials, chiefly limestones. In industrial districts the atmosphere may be heavily polluted with acid.

Acoustic Materials.—Materials used to ensure the satisfactory distribution of sound. There are two types : sound absorbing materials and sound reflecting materials. Sound absorbing materials are generally soft and of open texture (as cork, slag wool, fibre insulation board, sound absorbing plaster, quilted eel grass, hairfelt, strawboard, carpet and thick curtains and fabrics). Sound-reflecting materials are dense (as glass, clay tiles, cement concrete, marble, hard plasters, sheet metal, plywood and dense brickwork in cement mortar). The acoustic properties of materials may be compared by consulting a list of sound absorbing coefficients for a given frequency of sound waves. See Insulating Materials (see Vol. IV, Chapter 5).

Adhesives.—There are two distinct types used in building work : ordinary animal glue, and natural and synthetic resins. *Animal glue* in its cold state is a hard brown gelatin made by boiling animal hoofs and hides. Heated in water it becomes strongly adhesive and sets as it cools. Animal glue is not waterproof, and it softens when moisture reaches it. It is very brittle and should be used as thinly as possible, the work being held under pressure until the glue has set and hardened.

Resin glues come within the group of materials called Plastics (which see). There is a wide variety of synthetic resin glues in both hot and cold setting forms, each of which is suitable for certain types of work. Many are gap-filling and so can be used in a thick condition suitable for glueing large laminated wood members such as roof beams and trusses. These adhesives are widely used, notably in making water-resisting plywood. Resin glues undergo chemical changes when setting and are not thereafter affected by moisture. The use of these glues has led to interesting developments in the construction of laminated and prefabricated panels, beams, trusses and other structural members.

Aggregate.—Material used with cement and water to make concrete. In most concretes a comparatively coarse aggregate (broken brick, gravel, pebbles, for example) is used with a fine aggregate (sand). The term aggregate is sometimes applied to the coarse aggregate only, although it is properly applied to both coarse aggregate and sand. In specifying proportions, care should therefore be taken to avoid confusion.

Fine aggregate (sand) should be clean. If necessary it should be washed to remove organic or other impurities. Sea sand should be washed to remove salt which would otherwise cause efflorescence. Very fine sand is undesirable. The most suitable sand is graded up to as much as $\frac{1}{4}$ inch. A rounded sand is better than a sharp sand. Quarry grit, if of suitable material, may be used instead of pit sand.

Coarse aggregate may be taken from alluvial deposits such as pit gravel, pebbles, and beach shingle. Such material is usually graded for size by machinery and washed if necessary. Coarse aggregate may be broken down from natural rock and from bricks. Care must be taken to select material of suitable quality. It must be chemically inert, as otherwise concrete made with it may deteriorate. Good sandstones, limestones, whinstone and granite make good aggregates.

Sizes of coarse aggregate vary from $\frac{1}{8}$ inch up to 2 inch. Sizes vary according to use from about up to $\frac{1}{2}$ inch for granolithic work and up to $\frac{3}{4}$ inch for reinforced concrete to 2 inch for mass foundations (see Concrete).

Special aggregates are used for decoration, fireproofing, and partition slabs. Crushed coloured stones, marble, and spar are used for decorative floors and wall coverings. Pumice, crushed slag and hard clinker are used for fireproofing. Coke breeze is used for light partition slabs. Slag, clinker, and breeze must be free from chemicals like sulphur, and from all traces of unburnt coal. If such impurities are present chemical action will take place in the concrete when moisture is absorbed and the material will crack.

Average weight of brick and gravel aggregates : 112 lb. per cubic foot.

Alabaster.—The best *English alabaster* is a pure white gypsum with light brown streaks. It is soft and easily worked, but will not stand exposure to the weather and is therefore suitable only for internal decorative use.

The inferior material is ordinary gypsum (see Gypsum).

Oriental alabaster is a name sometimes given to onyx marble—a much harder material than English alabaster.

Alkali.—A series of basic chemical compounds which have the property of neutralising acids. Soda, potash and ammonia are examples. Alkalis are easily soluble in water and produce caustic or corrosive solutions.

Alkalis affect colours by turning vegetable yellows brown, reds to blue, and purples to green. When present in brick clay alkalis turn the brick to a greenish blue and also distort the shape.

Alkaline silicates (silica dissolved in caustic soda or potash) are used as

stone preservatives. By adding alkaline silicates to lime mortar the setting time is considerably reduced.

Alloy.—A compound metal consisting of two or more pure metals mixed together. An alloy may differ only slightly from the principal metal used in its composition, or it may have special qualities altogether different from its constituent metals.

Copper is used as a base metal in a number of alloys. Copper combined with a proportion of tin gives the alloy called *bronze*. Copper with zinc gives *brass*. The proportions vary and other substances are added, according to what qualities it is desired to have in the alloy (see Brass and Bronze).

Stainless steel is an alloy consisting chiefly of steel and chromium. *Monel metal* is another stainless alloy, widely used for good quality fittings.

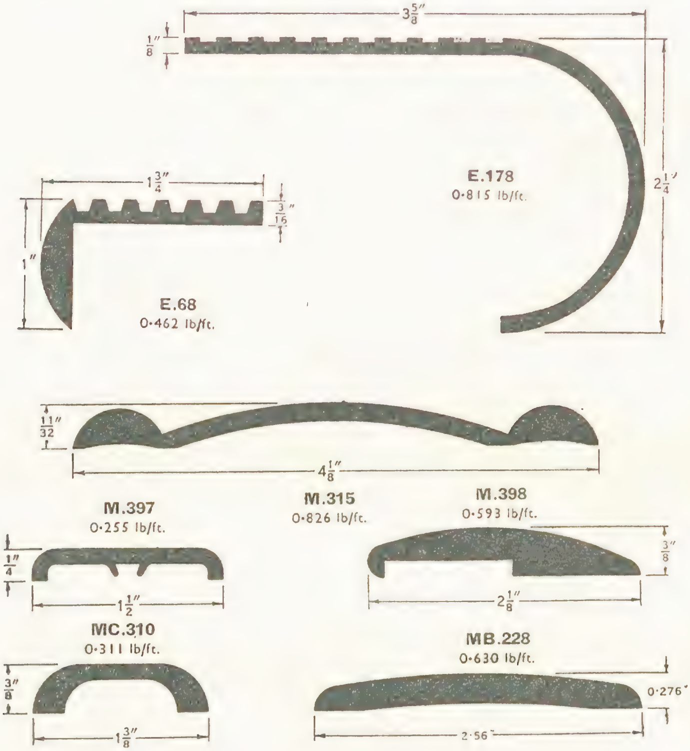


Fig. 201.—Aluminium Alloy Sections.
(*Top*) Stair Treads. (*Bottom*) Mouldings.

Alumina.—Oxide of aluminium—an earth. Present in brick clays it enables the brick to set and harden. It is used in combination with calcium to provide the setting action in aluminous cement, and also plays some part in the setting action of Portland cement (see Cements).

Aluminium.—A light grey ductile metal of comparatively light weight. In buildings it is used chiefly in alloy form. *Aluminium alloys* vary widely in physical properties. Some are very strong. Some have high resistance to corrosion. Others are suitable for casting, and some of the alloys can be wrought.

Aluminium is of light weight (165 lb. per cubic foot compared with 450 lb. per cubic foot for cast iron), and this is one of its most valuable properties. It is now being used for structural framework, and in suitable cases reduces the cost of the building owing to the weight saving.

Oxidation in normal atmospheres is slight and the highly polished sur-

face can be preserved by anodising. Coloured finishes can be obtained by electrolytic process.

Aluminium is made in sheet form—flat and corrugated—and in a wide variety of extruded sections, structural sections, rods, bars, and castings.

Aluminium paint consists of powdered paint suspended in varnish.

Weight of aluminium : approximately 165 lb. per cubic foot.

Aluminous Cement.—(See Cements.)

Artificial Stone.—(See Concrete Products.)

Artificial Marble.—(See Marble.)

Asbestos.—A mineral fibre of great tensile strength, fire resistance, and acid and alkali resistance. *White asbestos*—the type generally used for building materials—consists of silica and magnesia. *Blue asbestos*, which is used for special purposes where very high acid resistance is required, consists of silica and iron.

The name Asbestos is derived from a Greek word meaning indestructible, and the material does not deteriorate in any normal atmosphere. Asbestos is found chiefly in Canada, South Africa, Cyprus and Russia.

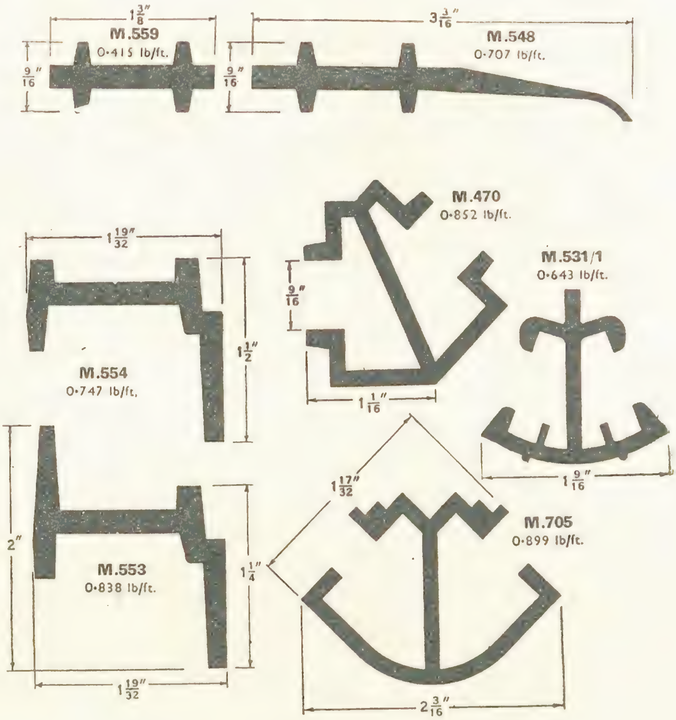


Fig. 202.—Aluminium Window Sections.

When quarried it is mechanically dried, crushed, fiberised and graded. The fibres are from $\frac{3}{4}$ inch to 3 inches long.

Asbestos is used in conjunction with Portland cement to make sheets and tiles (see Asbestos-cement). Asbestos is also used to make lagging for boilers and pipes—a purpose for which its high degree of thermal insulation makes it very well suited. Asbestos also has a high degree of sound resistance, and in a suitable form, is used for packing between floors and partitions to reduce sound transmission (see Insulating Materials).

Asbestos Board.—A wall and ceiling board of compressed asbestos fibre mixed with sodium silicate (see Building Board).

Asbestos-Cement.—A compressed composition of fiberised asbestos

and Portland cement. (Both materials are separately described under their respective names.) This composite material unites the great tensile strength of asbestos and the compressive strength of Portland cement. It is fireproof, weatherproof, and proof against atmospheric acids and alkalis. It is an exceptionally durable material and does not deteriorate in the impure atmosphere of industrial towns. Although of great strength, it is rather brittle and should be used as a covering, lining and facing material and not as a load-bearing material. Reinforced asbestos-cement, with metal reinforcing fabric incorporated in the material, will, however, stand considerable loads and shock.

The good qualities above described can only be obtained by correct manufacture. The best asbestos-cement consists of layers of fiberised asbestos and Portland cement united by passing through rolls which exert great pressure. The material is afterwards matured. In a sheet $\frac{3}{16}$ inch thick there are at least twenty-four layers. The finished sheet should not be regarded as a laminated sheet, since the heavy pressure of the rolls produces a homogeneous material.

Inferior asbestos-cement is made with asbestos powder and Portland cement, the material being produced in moulds. Although cheap such material is weak and liable to disintegration. All the reputable brands of asbestos-cement are made of fiberised asbestos as before described.

Asbestos-cement is of light weight, and transport and handling is easy. The natural colour is light grey. It can be obtained in various colours and in smooth or embossed finishes. The natural material requires no protection to ensure durability, but it may be painted or distempered, provided that a suitable primer is used. The material may be cut and drilled with suitable tools. Expansion and contraction of asbestos-cement is very little compared to such movements in steel and wood. It is therefore necessary to fix asbestos-cement products so as to allow for movement of the supporting material without straining the asbestos-cement. Tight fixing must be avoided.

Weight: approximately 120 lb. per cubic foot. Corrugated, $\frac{1}{4}$ inch thick, as laid, 3·3 lb. per square foot. Flat, $\frac{1}{4}$ inch thick, 2·3 lb. per square foot.

Asphalt.—Natural asphalt is a bituminous limestone containing about 10 per cent. of bitumen. As used for most purposes in building, it has an admixture of grit or rock chippings—coarse for pavings and other wearing surfaces and fine for roofs and weatherproofing. Fine asphalt (without grit) is used for special purposes such as making waterproof joints. Natural asphalt is a very durable material which remains stable in atmospheric extremes, is waterproof, tough and slightly elastic.

The raw material is found as asphaltic rock in France, Italy, Sicily and Switzerland, and as semi-liquid or lake asphalt in the West Indies.

There are two forms: mastic asphalt and powdered asphalt.

Mastic asphalt is produced by grinding asphaltic limestone to a fine powder and mixing with a proportion of clean grit. The powder is then

FIG. 203.—HARRODS ESCALATOR HALL.
View from first floor, showing escalator foot, door into store and side lamps on hall wall. Architect : J. L. Harvey, A.R.I.B.A.
(Courtesy of the British Aluminium Co., Ltd.)

FIG. 204.—CORBY PERMANENT HOUSE.

"Turnall" double cladding to upper storey, with "Poilite" moulded eaves units. Architects: Arcon.

(Courtesy of Turners Asbestos Cement Co.)

heated and mixed by power until it becomes mastic. This is cast into ½-cwt. blocks—the form in which it is delivered for use. Preparatory to use, it is melted in suitable cauldrons, spread while hot and worked with floats to the required thickness and surface.

Powdered asphalt is the natural powdered bituminous limestone reduced to a fine powder. In use it must be heated to a high temperature and subjected to great pressure as it is placed *in situ.*

The supporting and contacting surfaces on which asphalt is laid must be firm and dry. The slightly elastic nature of asphalt will allow slight settlement or expansion and contraction in the supporting materials, but if this is excessive the asphalt will crack. On flat roofs without parapets measures should be taken to turn the edges of the asphalt over the edges of the roof or otherwise to secure it as cases have occurred where the asphalt has been blown off the roof by severe gales.

Coloured asphalts are made which have a better appearance than the natural black tint. A special acid-resisting asphalt containing silica is made for use where such resistance is necessary. Ordinary asphalt is not proof against acids and oils, although it is proof against urine. Asphalt readily absorbs solar heat and the supporting material on roofs should therefore have a high degree of thermal insulation.

Weight : 112 lb. per cubic foot.

Ballast.—The term is applied generally to any hard filling material, including shingle, small stones, broken brick, slag, and broken concrete. The original application of the term was confined to the small stones and sand dredged from the Thames estuary.

Ballast may be classified and described according to the material and source. Thames ballast, much used in and around London, is an alluvial deposit of small pebbles graded in size and of light grey colour. It is clean, hard material. Pit ballast is gravel from glacial and alluvial deposits. This is found mixed with sand, from which it is separated by mechanical screening. It is usually washed to give clean material, and may also be graded for size.

Clean hard ballast is used as the coarse aggregate for concrete. Ballast is also used for filling under solid floors, for road making, and for surfacing. For paths small pea gravel or crushed ballast is used. This small material is also used with bitumen and tar for road and path surfacing. As a foundation or filler ballast should be well rammed or rolled with a heavy mechanical roller. As a surfacing material it is rolled.

Weight : approximately 112 lb. per cubic foot.

Bitumen.—A mineral material, of translucent black colour, sometimes found free and sometimes mixed with stone, sand, or clay. When found in combination with rock the mixture is used as asphalt (which see). Bitumen consists of 87 per cent. carbon, 11·2 per cent. hydrogen, and 1·8 per cent. oxygen. It is solid when cold, softens at about 60° C. and melts at about 100° C. It is waterproof and durable under all kinds of atmo-

spheric conditions, except that it softens in hot sunrays. It is slightly elastic and thus preserves its waterproof quality under settlement and expansion and contraction. It is affected by oils and is soluble in benzole. Bitumen is used in the following building materials :

Bituminous Materials.—Asphalt for floors, paths, roof coverings, etc. Macadamised road and path surfacings; cold emulsions for road and path surfacing; mastic for jointing and waterproofing; roofing felts of asbestos or other fibre impregnated with bitumen; building papers impregnated with bitumen; damp-proof courses consisting of pure sheet bitumen, bitumen covered lead, and asbestos fibre impregnated with bitumen. Bituminous paints and emulsions for use on metalwork and for water-proofing concrete surfaces (see Asphalt, Paint).

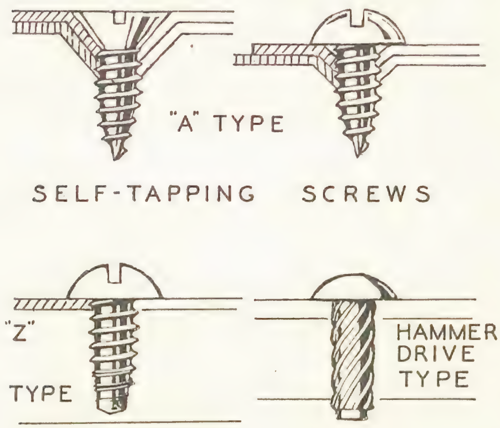


Fig. 205.—Nettlefold's Parker-Kalon Fastenings.

Blocks.—Building blocks are made of a variety of materials including burnt clay, terra-cotta, diatomaceous earth, normal and light-weight concretes, and plaster. They vary in size and shape from plain solid blocks to hollow keyed blocks of little more than brick size up to 2 feet × 1 foot. Thicknesses vary from $1\frac{1}{2}$ inches to 6 inches. Most blocks are hollow, or if solid of lightweight material. Various types are made for walls, partitions and floors.

For uses, see Vol. II, Chapter 4.

Weights :

Clay blocks	per 1 inch	of thickness, as laid,	5·25 lb.	per cubic	foot.
Concrete	,, 1 ,,	,, ,,	5·25	,,	,,
Diatomaceous earth		,, ,,	2·5	,,	,,

Brass.—An alloy of copper and zinc of proportions from 70 per cent. copper : 30 per cent. zinc, to 95 per cent. copper : 5 per cent. zinc, and of average weight 525 lb. per cubic foot. Strength and resistance to corrosion are directly proportional to the proportion of copper, though something depends on the method of manufacture. The greater the proportion of zinc the softer the alloy. Brass is produced in rolled sheet and strip, extruded sections, bars and tubes, and castings.

Brass rapidly tarnishes and a protective finish is usually given to the surface. Finishes include lacquering, transparent cellulosing, and the popular bronze metal antique (B.M.A.) which gives it a bronze colour. Chromium plating is also widely used.

Weight : Castings, 520 lb. per cubic foot.
Rolled sheet, 530 lb. per cubic foot.

Breeze.—Clinker or cinders left after coal has been burnt (see Concrete).
Weight : Loose, approximately, 45 lb. per cubic foot.

Brick.—(See Clay Products, Concrete, Sand-Lime.)

Bronze.—An alloy of copper, tin and zinc usually in the proportions of 88·5 per cent. copper, 9·75 per cent. tin and 1·75 per cent. zinc. Does not readily corrode and has medium strength. It is widely used for building fittings such as door furniture, window fittings and gearing for opening lights.

Weight : 553 lb. per cubic foot.

Building Boards.—Any sheet material other than natural wood, though chiefly fibre boards, asbestos board, and wood-plastic boards (which see).

Chalk.—Calcium carbonate, an earthy limestone. A white or very light grey material occurring in beds and widely distributed. In Britain it is usually rather soft and so unsuitable for building blocks, though it is occasional used for interior work. It readily absorbs water and then softens.

The chief uses of chalk are to supply calcium carbonate for the manufacture of limes and cements, and in pure powder form it is used as whiting to make whitewash and in the manufacture of distemper. Mixed with inseed oil whiting is used to make ordinary putty.

Cement.—A substance which develops setting and hardening properties in the presence of water. Once set it is no longer affected by moisture. It is strongly adhesive and hence used to mix with fine and coarse aggregates in making mortar and concrete.

The term cement is sometimes also applied to certain plastic adhesives for bonding wood and other materials (see Adhesives).

Portland cement, Portland rapid-hardening cement, and high-alumina or aluminous cement are the three types now widely used in building.

Portland cements are made from a mixture of limestone or chalk and clay or shale. There are three main stages of manufacture : mixture with water to form a slurry, drying and burning in a kiln and grinding the kiln clinker to form a powder. The cement powder consists of approximately 60 per cent. lime, 20 per cent. silica, and 5 to 10 per cent. alumina, with traces of other chemicals.

As Portland cement can vary widely in quality, it is important to see that it complies with British Standard No. 12 (current edition), though the reputable British brands exceed in quality the B.S. requirements.

When mixed with water the chief constituents of the cement form into hydrates, and then into silicates and aluminates. After setting, a small amount of free lime is left which is liable to react with other substances. In contact with some chemicals it may cause disintegration of cement concrete. Another consequence is the formation of efflorescent salts which are drawn to the surface in the form of a white deposit.

Portland blast-furnace cement is much the same as normal Portland

cement. In manufacture blast furnace slag is mixed with the cement clinker. This cement has a greater resistance to sulphates and to sea water than the normal type. Otherwise the qualities are similar.

Normal and blast furnace Portland cements attain their initial set within thirty minutes, and the final set within ten hours. If disturbed after the initial set, cement mixes will lose strength and cohesion, and must therefore be used within thirty minutes of mixing. After the final set the cement mix slowly increases in strength, attaining half its strength in three days and nearly its full strength in twenty-eight days.

Rapid-hardening Portland cement largely overcomes the disadvantage of slow hardening in normal Portland cement. The rapid hardening property is chiefly due to very fine grinding with resulting rapid hydration. The nearly full-strength period of twenty-eight days of normal cement is cut to four days with rapid-hardening cement. Setting time is not much faster, but the rapid gain of strength allows the concrete or cement mix to be brought into use in a much shorter time.

Aluminous or high alumina cement should not be confused with Portland rapid-hardening cement. The chief constituents of aluminous cement are chalk and bauxite, the latter being aluminium ore. So instead of calcium silicate we have calcium aluminate as the chief compound.

Aluminous cement has several advantages over Portland. The initial set is longer—$3\frac{1}{2}$ hours—which gives a much longer period after mixing during which the cement mix can stand before use. The final set is reached in about $4\frac{1}{2}$ hours and the strength exceeds that of normal Portland cement. An average strength is 6,000 lb. per square inch in 20 hours and 8,000 lb. in 24 hours. For most purposes the work can be fully loaded in 24 hours. Other advantages are: during the setting period considerable heat is given off and this protects the mix from frost down to about 20° F. below freezing; the density is greater and damp penetration very slow; free lime is not liberated and this renders aluminous cement mixes immune to seawater, neutral sulphate, sugar, beer, oils, sewage and many other substances which attack normal cement mixes. Aluminous cement is black and makes a much darker mix than Portland.

White and coloured cements, usually of the rapid-hardening type, are produced by adding pigments to Portland cement.

Roman cement is made by burning hard nodules found in London clay and lias shale beds. The cement contains about 40 per cent. clay and is not so strong as Portland cement. It has a rapid set and as it contains little free lime it can be used in ground containing sulphates.

Portland cement, weight, loose: 90 lb. per cubic foot.

Puzzolana, found in Italy and *Trass* found in Germany are similar to Roman cement. But Portland cements have so many advantages that these older cements are now rarely used.

Clay Products.—These include bricks, terra-cotta, roofing tiles, floor tiles and wall tiles, hollow floor and wall blocks, flue liners and chimney pots.

Clay bricks are made from clay and shale, which are called brick earths. The plastic raw material is processed to make it suitable for moulding. Brick earths consist chiefly of silica and alumina with small proportions of various oxides. The silica produces hardness and durability, the alumina gives a binding and setting action, and the oxide of iron affects the depth of colour and to some extent hardness. Marl, a mixture of clay and chalk, found in Kent and Essex, produces a light yellow brick due to the high proportion of chalk.

Machine-made bricks are processed and moulded by more or less elaborate plant, depending on the scale of production. Wire-cut bricks are made from plastic clays which are forced by a series of rotating blades through a rectangular orifice, producing a continuous column, which is cut across by stretched wires to form individual bricks. The wet clay bricks are then dried and fired in suitable kilns, and the burnt bricks have sharp arrises and smooth faces.

Re-pressed wire-cut bricks are produced by a similar process to ordinary wire-cuts, except that when semi-dry they are pressed by machinery to produce frogs or other marks and to make the clay more compact.

Pressed semi-dry bricks are now produced in large quantities. Flettons are of this type. The quarry clay is processed with only a small amount of water, and is compressed under very high pressure in moulds of brick-shape and then passes direct to the kilns. These bricks are smooth and of consistent shape and strength. A cellular brick, hollow inside, is also made by this process.

Hand-made bricks are still made by traditional methods, though on a small scale. The clay is allowed to weather for some time after digging and is then mixed with water to make it sufficiently plastic. Lumps of this plastic clay are then hand-thrown into the mould, the interior of which is usually sanded to prevent adhesion. Coloured sands are often used so that when the bricks are burnt they have a sand face of pleasant colour.

For the various types and classifications of bricks see Vol. II, Chapter I. (See also Sand-lime bricks, Flint bricks, and Concrete.)

Terra-cotta is made from very fine clays which are carefully selected and processed to produce fine textured material out of which terra-cotta hollow blocks and tiles or slabs are made for facing walls. All kinds of architectural features, including cornices, columns and mouldings, can be produced, but sizes of blocks are limited owing to distortion in firing. The hollow blocks are usually filled with fine concrete, except where large cornice blocks overhang.

Faience is glazed terra-cotta, vitreous or majolica enamelled. For modern work without elaborate detail, elevations are often faced with plain faience tiling. The glaze is impervious and highly resistant to atmospheric pollution, and the surface easily cleaned by washing.

See Vol. II, Chapter 4, for details.

Fireclay is refractory ; that is, it has high resistance to great heat. Fire-

clays are rich in silica and alumina. Colours vary from nearly white to blue and black. Bricks made from refractory clays are used for lining industrial flues. The clays are also used for making the best quality glazed sanitary ware and glazed bricks.

Brickwork weights :

Common, Flettons and London stocks, 125 lb. per cubic foot.
Heavy pressed bricks, 140 lb. per cubic foot.

Cob or Pise de Terre.—Earth containing a considerable amount of clay to which chopped straw may be added, and beaten down *in situ* to form walling. This is a traditional walling in the West of England. Walls are about 3 feet thick and are whitewashed for weather protection. (See Vol. II, Chapter 4.)

Compo.—Abbreviation of Composition. A mortar or plaster in which lime and cement are mixed with sand. (See Vol. I, Chapter 13.)

Concrete.—An artificial mixture of aggregate and cement, the cement enveloping the pieces of aggregate and setting hard in the presence of water. The aggregate consists of coarse aggregate (see Aggregate) and fine aggregate (see Sand). Portland or aluminous cement is used as a binder (see Cement).

A strong concrete, almost impervious to water, can be produced by selecting, grading, proportioning and mixing by carefully controlled methods which closes all voids between the particles of aggregate, each particle being surrounded by a film of cement. To achieve maximum density the coarse aggregate should be graded in size from pieces that will just be retained on $\frac{1}{8}$-inch mesh screen to pieces that will just pass $\frac{3}{4}$-inch mesh. The sand should be clean and rounded, and well graded from small particles up to particles just passing through a $\frac{1}{8}$-inch mesh. It is important to exclude earth, clay, vegetable matter and harmful chemicals.

Voids and the percentage of cement required to fill them can be determined by simple tests, as described in Chapter 7, Vol. II.

Very dense concrete is required for reinforced work to carry heavy loads, and where resistance to water penetration is required. But dense concrete encourages condensation and is of low thermal insulation value.

Medium and high porosity concretes are often desirable, though for outside walls a surface skin of dense concrete or rendering may be necessary to make the material weatherproof. Porosity can be produced by using coarse aggregates of open texture and by leaving the voids between particles of aggregate mostly unfilled or partly filled.

No-fines concrete is concrete of open porous texture produced by omitting the sand. A typical mix is 1 : 8 with water sparingly used. The mix is stiff and can be placed in wall shuttering of expanded metal on a light frame. Walls of no-fines have high thermal insulation, but must be protected outside by cement rendering.

Lightweight concretes are made by using lightweight aggregates. Foamed slag, clinker and pumice are widely used lightweight aggregates. They

are very porous, hence the light weight, and must be well wetted before adding the cement so that the cement is not drawn into the pores.

Cellular or aerated concrete is a lightweight concrete produced by creating cells separated from one another by walls of cement. By one method, aluminium powder is mixed with Portland cement and within twenty minutes of adding water hydrogen is generated, the cement expands and the bubbles form the cells or cavities. By another method, resin soap is used as a foaming agent. The expansion may increase the overall volume of the mix by from 25 to 100 per cent., according to the amount of aluminium powder or resin soap used. Clinker or other lightweight aggregate is used without sand. The thermal and sound insulation is high and the material is widely used for partition and wall-lining blocks. It can be sawn, and nails driven in.

Concrete weights :	Ballast or stone . .	140	lb. per	cubic foot
	Brick	115	,,	,,
	Clinker	90	,,	,,
	Pumice	70	,,	,,
	Reinforced (2 per cent. steel)	150	,,	,,

Concrete Products.—Pre-cast products of concrete are of three main types : (1) of fine concrete, (2) pigmented to an approximate imitation of stone, and (3) of crushed stone aggregates to make *reconstructed stone.*

In class 1 we have a wide range of products of which pipes, lintels, slabs, wall blocks and reinforced floor beams are typical. In class 2 we have wall blocks for outside facing, slabs and steps. In class 3 we have reconstructed stone facing blocks specially made to the architect's designs.

The aggregates normally used for pre-cast products are of small size, the maximum passing a $\frac{3}{4}$-inch ring, and the work is cast in wood or metal moulds on a mechanically vibrated table which thoroughly consolidates the material. The products are then " cured " by being kept moist for several days and then being slowly dried.

(See Vol. II, Chapter 11.)

Weights : See Concrete.

Copper.—A reddish coloured metal which oxidises in air to form a protective coat, though further oxidation may occur in polluted atmosphere. In a fairly clean atmosphere the oxidised surface gradually assumes a green patina, but in a polluted atmosphere further corrosion turns the surface black. Copper can be plated or enamelled, but the natural surface can be periodically cleaned with linseed oil or vaselene.

Copper is an excellent electricity conductor and is almost exclusively used for electric cables. In building it is used for roofing, gutters and water pipes.

Copper is produced from ores mined in many countries, including North and South America, most European countries, Japan, Australia and Africa. There are three commercial grades : High Conductivity, used chiefly for electric cables; Best Select, a refined copper containing small

amounts of impurities and widely used for many purposes; Arsenical Copper, containing about ½ per cent. arsenic which toughens the metal and makes it suitable for many general purposes.

(See Vol. II, Chapter 17.)

Weight : Roofing sheet (24 s.w.g.) as laid, 1·33 lb. per square foot.
Wrought copper, 555 lb. per cubic foot.

Corrugated Iron.—(See Steel and Iron.)

Weight : 18 B.G. galvanised, as laid, 2·72 lb. per square foot.

Cork.—(See Insulating Materials.)

Creosote.—(See Preservatives—Wood.)

Diatomaceous Earth.—A siliceous earth formed by fossil deposits, of grey colour. Used in the manufacture of fire-resisting partition blocks and fire bricks, and fire-resisting composition building board.

Weight in blocks, per inch thickness : 2·5 lb. per square foot.

Distemper.—(See Paints.)

Eel Grass.—(See Insulating Materials.)

Faience.—(See Clay Products.)

Fibre Building Boards.—Rigid sheets composed chiefly of wood or other vegetable fibre. Some boards are homogeneous and some are laminated. One type is treated with bitumen to give moisture resistance.

Fibre boards are compressed in manufacture and the degree of compression has a marked effect on density and strength. There are three distinct types, according to the relative density : (1) *Insulating boards* of low density and not less than ½ inch thick—they have good thermal and sound insulating properties and a surface which can be decorated; (2) *Wallboards* of medium density, widely used in thicknesses of ⅜ inch and ¼ inch for lining walls and ceilings, though the insulating value is rather low; (3) *Hardboards* highly compressed and of considerable strength, subdivided into Medium, Standard and Super according to density. In many ways superior to natural wood.

(See Vol. III, Chapter 13.)

Weights :	Insulating boards . .	25 lb. per cubic foot.
	Medium hardboard . .	30-48 lb. per cubic foot.
	Standard hardboard . .	50 lb. per cubic foot.

Firebrick and Fireclay.—(See Clay Products.)

Flint Brick, or "*Hunziker*" brick.—Made of flint ballast and ground lime, processed and subjected to very great pressure. Silver grey and other light colours are made. Flint bricks are of great strength, consistent size, great density, good light reflection and good appearance. They are suitable for heavy loads and also for facing work.

Fleximers.—The name given to a group of floorings, of recent introduction, consisting of rubber latex cement or certain plastic materials mixed with a variety of aggregates from marble to wood chippings and

FIG. 206.—ALFOL REINFORCED ALUMINIUM FOIL BEING FITTED TO A FACTORY ROOF.
(Courtesy of Alfol Insulation, Ltd.)

FIG. 207.—STRAMIT WALLS AT THE WOLSEY FACTORY AT LEICESTER. THIS SHEET MATERIAL IS LICENCE-FREE.

FIG. 208.—CEILING OF HALF-INCH TENTEST COMPLETED BY SPRING-CLIP METHOD.

(Courtesy of the Tentest Fibre Board Co., Ltd.)

FIG. 209.—CLOSE-UP OF THE CELOTEX "COVER PANEL" (OVER PURLIN) SYSTEM OF FIXING.

(Courtesy of Celotex, Ltd.)

coloured with suitable pigments. The main characteristic of fleximer floorings is that they remain flexible, though the degree of flexibility varies with the composition. Fleximers are laid *in situ* in thicknesses of from $\frac{1}{4}$ inch to $\frac{5}{8}$ inch. They are not affected by damp but some are quickly affected by grease and acids.

Rubber latex cement is used in most fleximer mixes. It is a mixture of a latex of natural rubber or reclaimed rubber with aluminous cement—though normal Portland cement can be used if the longer setting time is not objected to—with aggregate and pigments. The most common aggregates are wood chippings or granules, wood flour, cork, spar and marble. The harder the aggregate the harder wearing the floor. The softer the aggregate the quieter and warmer the floor.

For light duty floors, as in houses, fleximers are laid in one coat $\frac{1}{4}$ inch thick, the material being spread and floated immediately after mixing. This work is done by specialist contractors. Washing and wax polishing are necessary to maintain the surface.

Apart from rubber latex certain synthetic resins (plastics) are used, some with very high resistance to oils and acids.

Foamed Slag.—(See Concrete.)

Glass.—Silica, soda and lime are the chief ingredients of glass. They are melted together at temperatures rising to 1530° C. At a temperature suitable for working, the glass is vertically drawn in a " ribbon " to make sheet glass, or is cast or rolled.

Drawn sheet glass is used for most glazing in buildings, the usual weight being 24 oz. per square foot, but there are also 18, 26 and 32 oz. weights. There are three qualities : Ordinary Glazing, Selected Glazing, and Special Selected. Ordinary glazing quality is most commonly used, but the other two are of better quality with less distortion of vision.

Polished plate glass is ground and polished on both sides and there is no distortion of vision. The usual thickness is $\frac{1}{4}$ inch, though there are various thicknesses from $\frac{1}{8}$ inch to $1\frac{1}{4}$ inch.

Rough cast and figured glasses are made to obscure the view. Wired cast glass is made with a wire mesh embedded in it to act as reinforcement and prevent the glass flying about if broken by impact or fire.

There are many special glasses (see Vol. IV, Chapter 8).

Glass hollow bricks are made with sanded sides for laying in mortar. Thus walls of glass are built which admit light without vision and have much better thermal and sound insulation than ordinary windows.

Weight of glass sheet : per $\frac{3}{16}$ inch of thickness, 2·75 lb. per square foot.
" " " $\frac{1}{4}$ " " 3·5 " "

Granite.—(See Stone.)

Grout.—A very thin mortar produced by adding water until the mix runs freely. Used for pouring into crevices, especially in repair work.

Gypsum.—A soft stone consisting of hydrated calcium sulphate. The white fine-textured stone is called Alabaster. But there are also grey,

brown and black kinds of gypsum. Gypsum is quarried in Derbyshire, Nottinghamshire, Cheshire and Westmorland. Large quantities are used in the manufacture of gypsum plasters (see Plaster).

Hardboard.—(See Fibre Building Board.)

Hardcore.—Any hard material suitable for making up levels under floors, paths, etc. Old broken brick spoil from demolished buildings is the most common hardcore.

Weight, brick : 112 lb. per cubic foot.

Hardener.—Compound for treating concrete floors, incorporated in the concrete or applied to the surface of the finished floor, to harden the surface concrete, increase resistance to abrasive wear and prevent dusting up. Silicate of soda (waterglass) acts as a hardener when applied to the finished surface. But there are many proprietary hardeners specially prepared which give good and consistent results. Some incorporate ground steel to give very hard wearing floorings.

Insulation Board.—(See Fibre Building Board.)

Insulating Materials.—Materials which have high resistance to the passage of (1) Heat or (2) Sound. Those in class 1 are called Thermal Insulators, and in class 2 Sound Insulators. All materials of low density and open texture have good insulating properties against both heat and sound.

(1) *Thermal Insulators.*—These may be divided into three types according to the forms in which they are manufactured : Sheets rigid enough to be used as wall and ceiling linings; Quilts of loose material between Kraft paper and other flexible material delivered in rolls, such as hair felt; Loose material, such as sawdust and gypsum. Some of the chief insulating materials are listed herewith. The unit k is the thermal conductivity in B.Th.U. per square foot, per inch thickness, per deg. Fah., per hour. The lower this value the better the thermal insulation.

(2) *Sound Insulators.*—The low density porous materials which are good thermal insulators are also good sound insulators. The more rigid a material is the greater the sympathetic vibration set up by sound waves, and this effect greatly reduces the sound insulation value of building boards and thin sheets such as fibre board and plaster board. Some of the newer materials such as expanded rubber and expanded thermosetting plastics are valuable sound insulators.

Most materials specifically intended for sound insulation are sold under proprietary names, and the makers give technical information so that the sound absorption value may be judged.

The table on page 353 gives the essential data regarding some of the most common thermal and sound insulating materials.

Lead.—A heavy grey-toned metal obtained from the mineral galena, a compound of lead and sulphur, mined and smelted in the U.S.A., Spain, Germany, Mexico, Australia, Canada and Burma, and to a small extent in England. After refining, commercial lead of 99·95 per cent. purity

Fig. 210.—EXAMPLE OF THE CELOTEX "SECURING PLATE" SYSTEM OF FIXING.
(Courtesy of Celotex, Ltd.)

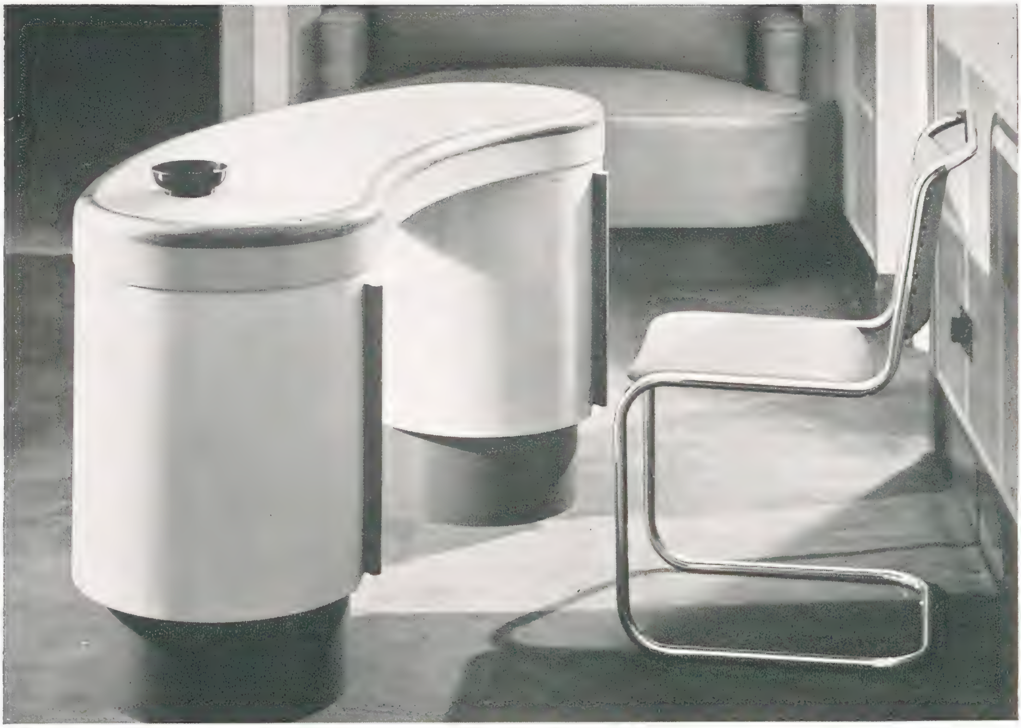


FIG. 211.—" WARERITE " MATERIALS.

An attractive example of the furniture-maker's craft employing " Warerite " materials. The top and cylindrical columns of the desk are surfaced with " Warerite " veneers. The edge of the upper surface is finished off in natural oak.

(Courtesy of Bakelite, Ltd.)

FIG. 212.—FIRST-CLASS SMOKE-ROOM ON S.S. *REGISTAN*.

Bulkheading of veneered panels with lining strips for gold beading.

(Courtesy of Holoplast, Ltd.)

is produced. It is manufactured in sheet and pipe forms for use in building.

Lead is very durable even in polluted atmospheres. It tarnishes in air, but the oxidised film thus formed is a protection against further corrosion. It is immune to attack by many chemicals which attack zinc and iron. It is soft and easily worked but has a high coefficient of expansion and low strength.

Sheet lead for roofing and flashings is from 4 to 7 lb. per square foot. Lead pipes are made in internal diameters from $\frac{1}{8}$ inch to 12 inches.

Material	Form	Weight per cu.ft./lb.	k⊕	sc*
Aluminium, corrugated	foil	—	·21	—
Cork	board	7–14	·27–·34	·35 at 9 lbs.
Fibre insulation	board	18	·35	·35 at ½ in.
Plaster-gypsum	board	60	1·10	
Plaster	floated	6 lb. per sq.ft.	2·00 at ¾	
Eel grass	quilt	4·6	·26	·50 at $\frac{1}{8}$ in.
Expanded plastics	sheets	6–10	·28	·45 to ·50
Hair felt	rolls	12	·26	·5 to ·75
Gypsum	loose	12–30	·44–·10	
Slag wool	quilt	10–20	.30–·27	·90
Sawdust	loose		1·04	
Shavings	loose		·71	
Wood—pine	board	31	·78	
Wood-wool	slabs	36	·58	·75
Brickwork in lime	walls	120	4·00	
Brickwork in cement	walls	120	7·00	
Concrete, dense	walls and floors	140	8·30	
Concrete, cellular	do.	40–70	1·06–2·18	
Concrete, breeze	do.	110	5·20	
Concrete, pumice	do.	73	1·62	
Glass silk	quilt	10	·21	
Rubber—expanded	rolls	20–25	—	·30

For data regarding wall construction see table on page 310, vol. IV.

⊕k—thermal conductivity.
*sc—sound absorption coefficient.

Lead alloys containing cadmium, antinomy, tin or tellurium are made which are tougher and stronger than pure lead and, although they cost more, thinner sheet and lighter pipe can be used. Waterworks authorities allow a reduction of 30 per cent. in pipe weights where ternary alloy No. 2 is used.

(See Vol. II, Chapter 17.)

Weights : Lead, 707 lb. per cubic foot.

Sheet per $\frac{1}{10}$ in. thickness, as laid, 8 lb. per square foot.

Lime.—A product made by heating or calcining natural limestone (calcium carbonate). This produces calcium monoxide, an alkali which combines readily with water, considerable heat being generated in the process. This process is called hydration. Hence lime which has been hydrated, dried and powdered in manufacture is called hydrated lime.

There are slight impurities in the limestone from which lime is made—clay, magnesium, silica and iron oxide—and these substances increase the

setting and hardening quality of the mortar. According to the amount of impurities the lime is classed and used for various purposes, as follows.

Pure lime has no strength in mortar but is used as whiting in whitewash and distemper, where it combines with the carbon dioxide in the air to form calcium carbonate.

Hydraulic limes have a setting property due to the presence of impurities. They are generally divided into weak, moderate and strong. The chalk limes, used to make plaster, are very weakly hydraulic, and are made from chalk. Stone limes are moderately hydraulic, and are made from limestone.

Lias limes are strongly hydraulic and are made from stones of the lias formation. Some of these stones are blue and some white. The setting action resembles that of Portland cement though it is not so strong.

(See Plasters.)

Weight : Loose lime, 50 lb. per cubic foot.

Limewash.—(See Paints.)

Magnesium Oxychloride Composition.—Commonly known as "composition" flooring (though there are many other compositions used for this purpose). Calcined magnesite, which is magnesium oxide in the form of a fine white powder, is used with magnesium chloride solution to produce chemical reaction and setting. Various fillers are added to produce a flooring of suitable structure; these include wood flour, sawdust and silica. Pigments are added to give required colours. The composition is floated on a concrete sub-floor, and considerable skill is required in mixing and floating. The sub-floor must be damp-proof, as rising damp disrupts this type of flooring.

Mastic Jointing.—Materials used for jointing where a permanent elastic property is required. Most jointing mastics are of a bituminous nature and some incorporate fillers of asbestos fibre. They are used between frames and wall jambs, between prefabricated sections, between glass bricks and brickwork, for stopping small holes and repairing cracks and fissures, and other positions where mortar or putty would be liable to shrink or crack. There are several proprietary brands, and special "guns" are made for injecting the mastic into narrow gaps.

Metals.—There are two groups: ferrous (iron and steel) and non-ferrous (containing no iron). *Ferrous metals* are described under Steel and Iron. *Non-ferrous metals* under Aluminium, Brass, Bronze, Copper, Lead, Monel, Zinc.

Monel Metal.—An alloy of nickel and copper with small amounts of manganese iron and other substances. It has high resistance to corrosion even in polluted atmospheres and will also resist solutions of most acids and alkalis. It is made in sheet, rods, wire, tube and cast forms. It is metallic white and takes a high polish which is easily retained by occasional washing.

FIG. 213.—LONG DESK AND PIGEON HOLES AT BRITISH EUROPEAN AIRWAYS. BOTH VENEERED PANELS AND FLEXIBLE VENEERS USED.

FIG. 214.—FREE STANDING PARTITION AT OXFORD CAR CO.
(Both photos by courtesy of Holoplast, Ltd.)

Fig. 215.—CORRUGATED "PERSPEX" ROOFING AT LEA HEAD FARM, NR. MIDDLEWICH.

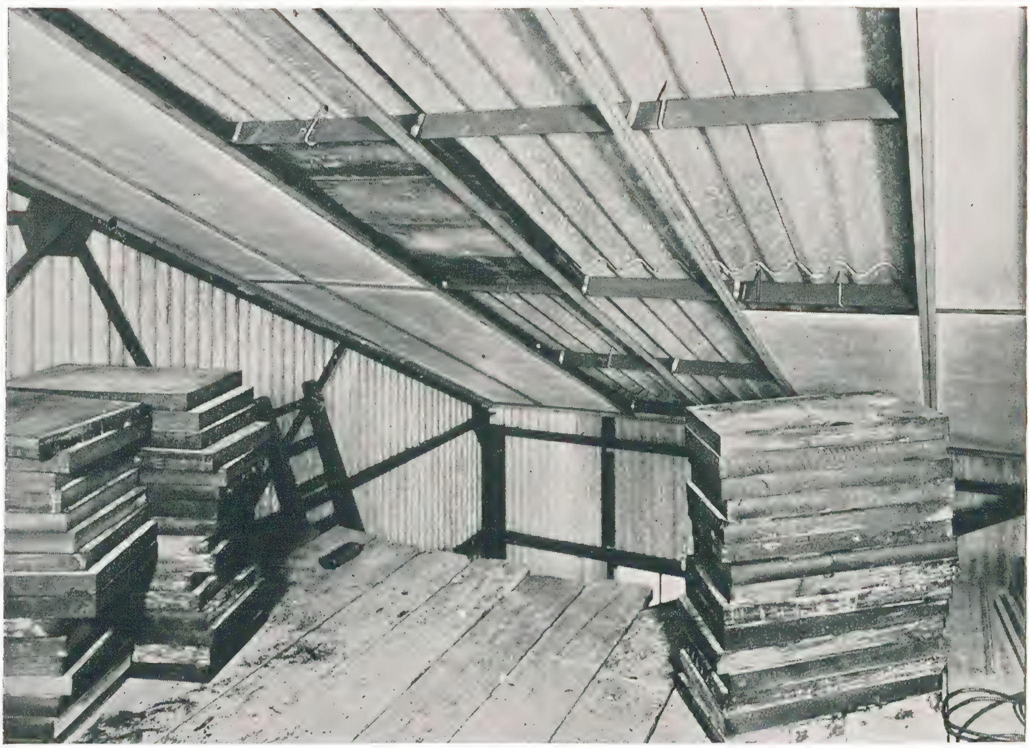


Fig. 216.—ROOF OF WORKS CANTEEN INSULATED WITH 2-IN. "ONAZOTE."
Note easy fixing to cross-members to which internal lining sheets are held.
(Courtesy of the Expanded Rubber Co., Ltd.)

Weight : 0·318 lb. per cubic inch. Expansion coefficient, ·000015 per deg. Cent.

Mortars.—An adhesive, hard-setting and durable material used to bind together bricks and blocks. Portland cement, aluminous cement, and lime are used as binders and adhesives with sand, and occasionally ground clinker, as aggregate.

There are three commonly used types of mortar : (1) *Cement mortar*, consisting of Portland cement and sand. (2) *Lime-cement mortar*, consisting of non-hydraulic lime, Portland cement and sand. (3) *Lime mortar*, consisting of hydraulic lime and sand. Special mortars are made for fireclay brickwork. These consist of mixtures of silica rock, sand and fireclay, or raw and burnt fireclay. The mortars should approximate to the same composition as the firebrick.

Mortars should have about the same strength as the bricks or stones with which they are used.

(See Volume I, Chapter 13.)

Lime mortar, weight : 103 lb. per cubic foot } 6 lb. per square foot,
Cement mortar, weight : 105 lb. per cubic foot } ½ inch thick.

Paints and Varnishes.—Paints consist of solid material carried in a liquid medium to enable them to be applied by brush or spray to surfaces. When the medium dries the solid material is left as a thin dense film.

In practice there are four kinds of material in oil paint : (1) *the pigment*, which is the solid material in powder form, giving the paint body and opacity as well as colour; (2) *the vehicle*, which carries the pigment in an even film and which solidifies on drying; (3) *the volatile thinner*, which helps to produce an even film of paint; (4) *the drier*, which assists drying and hardening of the paint film.

The chief *pigments* are : white lead, zinc oxide, lithopone, antimony oxide and tintanium oxide. A combination of white lead and zinc oxide is considered the best for outdoor work on wood.

The chief *vehicles* are : linseed oil, oil and resin.

The chief *volatile thinners* are : turpentine and white spirit. Naptha is used in some primers, but has an unpleasant odour.

For water paints, water is the thinner. In spirit varnishes and lacquers several chemicals are used, chiefly methylated spirit.

Driers used with oil paints are metal compounds, chiefly of lead, manganese and cobalt. They are prepared in two forms : as a paste and as a liquid called terebine, the liquid consisting of the driers in turpentine or white spirit.

Most oil paints are now factory mixed and sold under proprietary names.

Priming paints are specially compounded to suit the material to be covered. They should penetrate and adhere well, should be durable and provide a good surface for the subsequent paint coats.

Flat paints dry with a matt surface or a semi-gloss. They contain a

lower proportion of oil than gloss paints. Undercoat paints are of the flat type and give a suitable foundation for the finishing coats.

Gloss paint is ordinary oil paint drying with a moderate gloss. *Hard-gloss paint* contains varnish, synthetic resins or other materials intended to give a better flow and spread from the brush so that they dry with a high gloss and no brush marks. Enamel paints are now indistinguishable from hard-gloss paints, the name " enamel " being a misnomer.

Aluminium and *bronze paints* consist of small flakes of the metal in a vehicle of cellulose or oil varnish.

Cellulose paints consist of finely ground pigments in a nitro-cellulose medium, the latter being made by chemical treatment of cotton. These paints give a high-gloss finish and dry very rapidly, but are not suitable for brush application as a second coat acts as a solvent on the first. They are widely used for spraying large surfaces.

Water paints have the pigments carried in water as a vehicle. Distemper is a water paint with casein lime and borax, the casein acting as a binder which is not affected by water when dry.

Oil-bound water paint is an emulsion of oil and water, with pigments, usually supplied as a paste for thinning with water immediately before use, though some makers recommend dilution with a dilute medium or petrifying liquid as this gives a more durable paint film.

Bituminous water paint is also an emulsion mixed with water. It is used chiefly for painting on outside wall surfaces. It does not seal the pores but is moisture repellant.

Bituminous paint (not to be confused with bituminous water paint or emulsion) consists of bitumen in a drying oil with additional driers and thinners. This paint is durable and provides exceptional protection to steel and wood. But the range of colours is small and the tones rather dull. Bitumen cannot be painted over with ordinary oil paint, as the oil acts as a solvent to the bitumen, which would then bleed through. Tar paints resemble bituminous paints and have the same characteristics.

Cement Paints consist of Portland cement with added chemicals to give suitable working properties. They are made in white and a range of colours, for which alkali-proof pigments only are suitable. They are supplied as powders for mixing with water. Cement paints are suitable for brick, concrete and plaster, but not for wood.

Stone paints are oil paints with crushed stone as a pigment. Other special paints are : fire retarding paints based on silicate of soda and asbestos powder, heat-resisting paints for use on radiators and flue pipes, luminous paints made with phosphorescent pigments, and fungicidal paints which contain substances poisonous to fungi and so prevent mould growths in damp situations.

Varnishes are of two types : oil varnishes and spirit varnishes. Oil varnishes are made by mixing heated resin and heated oil, adding driers and thinners. For outside work the proportion of oil is high, as this gives maximum durability against weather attack. For inside work a higher

proportion of resin is preferred as this gives a harder and quicker drying varnish.

Spirit varnishes are made by dissolving soft resins such as shellac in turpentine or alcohol. They give a brilliant quick-drying finish, but are not as durable as oil varnishes.

Knotting is essentially a spirit varnish—a thin spirit solution of shellac—which seals the knot and remains insoluble when the paint is applied.

Stains are of four types : oil, spirit, water and creosote.

Oil stains are thin oil paints, the proportion of pigment being much less than with oil paint.

Spirit stains are solutions of dyes or transparent pigments in methylated spirit. They leave the grain of the wood clearly visible and tend to "raise" it.

Water stains are solutions of dyes in water. The work must be varnished over if it is not to be affected by moisture. Water stains tend to raise the grain.

Creosote stains in shades of brown, red and green are made of refined creosote and are suitable especially for exterior woodwork. But it is impossible to apply oil paint over them.

Weights : Paints, ready mixed, 50-80 lb. per cubic foot.
White lead, dry, 86 lb. per cubic foot.
White lead, paste, 174 lb. per cubic foot.

Pigments.—Coloured compounds which are used chiefly in paints and cements to give colour. In paints the principal pigment is the solid base of the paint—white lead, for example—and additional pigments to give the required colour are added. Most pigments are oxides or hydroxides of metals.

Pise de Terre.—(See Cob.)

Pitch Mastic.—A flooring material consisting of a coal tar pitch binder with fine and coarse aggregates of calcareous material, in some cases with the addition of an absorbent filler. Pitch mastic resembles asphalt.

Plaster of Paris. (Calcium sulphate hemihydrate).—Calcined gypsum, which when mixed with water sets and hardens within a few minutes. It is used for special purposes in plastering, mainly in repairs.

(See Gypsum and Plaster.)

Plaster.—A mixture of binding and setting material with fine aggregate. Plasters are made with lime and sand, with lime, Portland cement and sand, and with a gypsum material and sand.

(See Lime, Portland Cement, Gypsum.)

Lime plasters are made with either lime putty, run in a pit from lump quicklime, or hydrated lime in powder form. Mildly hydraulic limes are sometimes used, but generally lime plaster has little strength and is now only used in undercoats, for which its good insulation properties has advantages.

Lime-cement plasters are lime plasters gauged with a small proportion

of Portland cement to give strength. They are being increasingly used instead of plain lime plaster.

Gypsum plasters are made by calcining and processing gypsum. Calcined gypsum is plaster of paris, which sets hard in a few minutes and is therefore only suitable for small moulding, ornamental work and repairs. *Retarders* are added to lengthen the setting period and numbers of proprietary plasters are made of this type. They are known as *retarded hemihydrate gypsum plaster* and are made in three types : for undercoats, for finishing coats, and for use as both. A special type is made for application to plasterboard lath, and this type has very low expansion. These plasters do not commence to set for some little time, but the setting when it occurs is rapid. Shrinkage is negligible.

Anhydrous gypsum plaster is another type, produced by heating the gypsum to higher temperatures which has the effect of greatly reducing the reaction to water. *Accelerators* (alum, potassium sulphate and zinc sulphate) are added to give a suitable reaction to water. But the setting action is slower than with the hemihydrate type. Modifications of this process produce plasters of the Keene's and Parian type. Another type is known as *anhydrite plaster*, made from natural anhydrite. All gypsum and anhydrite plasters must be carefully used to the maker's instructions, as the different brands have individual characteristics.

Hair is used in some plasters, particularly on ceilings. It is essential in lime plastered ceilings, but with gypsum plaster its advantage is more in ease of application to an overhead surface than in producing a better plaster. Some plasters are sold ready mixed with hair, and some contain sisal fibres which have a similar effect.

Special plasters are made for acoustic and thermal insulation. These have a cellular low-density structure.

Weights :	Fibrous plasters, $\frac{5}{8}$ inch . .	3 lb. per square foot.
	Gypsum or lime, $\frac{1}{2}$ inch . .	5 ,, ,,
	Cement rendering, $\frac{1}{2}$ inch .	6 ,, ,,
	Add $1\frac{1}{4}$ lb. for wood or metal lathing.	

Plasterboard.—Consists of gypsum type plaster faced both sides with lining paper. Some types are suitable for finishing with plaster. Gypsum wallboard is smooth-faced for use as a lining finish to walls, partitions and ceilings.

On gypsum lath a suitable gypsum type plaster must be used for a finishing coat. Not all gypsum plasters are suitable, and the maker's instructions should be followed.

Plastics.—A group of materials which in the process of manufacture become plastic when heated and are then shaped under pressure.

There are many plastic materials, mostly synthetic. The following table classifies the chief plastics :

Natural.—Shellac, Bitumen.

Semi-synthetic.—Casein, Cellulose acetate, Cellulose butyrate, Cellu-

CEILING OF A CANTEEN FOR SIEBE GORMAN.

Insulated with "Onazote" $1\frac{1}{2}$ in. thick. "Onazote" was used to replace previous insulation of cork which became saturated due to steam.
(Courtesy of the Expanded Rubber Co., Ltd.)

Fig. 218.—RUBBER FLOORING.

(Courtesy of Redferns Rubber Works, Ltd.)

lose acetate-butyrate, Cellulose nitrate, Benzyl cellulose, Ethyl Cellulose.

Synthetic.—Phenol-formaldehyde, Urea-formaldehyde, Furfural formaldehyde, Melamine-formaldehyde, Nylon and other Polymides, Polyvinyl acetate, Polyvinyl chloride, Polyvinyl chloracetate, Polyvinyl acetals, Polystyrene, Polyethylene, Polyvinylidene chloride.

These and many other plastics are derived frcm a wide range of common materials, including coal, water, limestone, wood and milk. The chemical processes and changes are complex. *Fillers*, such as wood flour, and *plasticisers* are used to produce materials of suitable structure for various purposes. Pigments are used for colouring, both in plain and mixed colours.

Materials such as rubber and glass are not included in the Plastics group, though they have something in common as they are manipulated when hot. Rubber and leather are used in combination with certain plastics.

Plastic materials are often called synthetic resins and, generally, the two terms mean the same. There are two main groups of resins : Thermosetting and Thermoplastic.

Thermosetting resins, after heat and pressure treatment to produce the manufactured article, change in character so that they cannot be softened again by re-heating. Most plastics used in building are of the thermosetting type.

Thermoplastic resins regain plasticity if heated after manufacture. For many purposes this is no disadvantage if the softening point is fairly high, but with some thermoplastic materials it is inconveniently low.

Moulded plastic goods are made by mixing the synthetic resin with suitable fillers, such as wood flour, asbestos fibre and shredded canvas, placing the material in a heated steel mould, closing the mould and applying pressure. Metal inserts or metal reinforcement can be placed in the moulds so that they are fixed in the article.

Sheet plastics are, in most cases, laminated. *Laminated plastics* are made by impregnating sheets of paper of fabric with a solution of thermosetting resin. The sheets are laid on one another, dried and then pressed between heated plattens, the effect being thoroughly to bond the laminations together.

An interesting variation of the laminated process is the veneering of the sheet with wood. In fact any sheet material can be bonded to other sheets by the process. Sheets for tables and counter tops, for example, have an underlying metal sheet which, by rapidly conducting the heat away, prevents charring from cigarette ends.

Hollow panels of laminated plastic are made in which two flat panels are united with spacing strips. Hollow panels are used for partitions and doors and other large rigid surfaces.

Tubes and bars, and also moulded shapes, can be made with laminated plastics. The laminated process produces a much stronger material than the moulded process.

Resin-bonded plywood may be considered as laminations of plastic and wood, in which the wood layers are bonded together with synthetic resin instead of the glue used in ordinary plywood. The resin-bonded sheets have high resistance to damp. Resin-bonded plywood is made in tubular, channel and other structural forms as well as in flat sheets. Complex structural shapes are produced by moulding the material over suitable forms.

The autoclave, or rubber-bag process of moulding is used for large units, such as aircraft fuselages. The resin treated layers are placed over the mould which is then placed in a pressure tank (autoclave) where a rubber bag or sheet covers it and allows uniform pressure to be exerted by steam or air, the temperature being raised to about 240° F. to set the resin glue.

Improved wood is a laminated material similar in principle to resin-bonded plywood, but of very great strength and damp resistance. It is intermediate in character between wood and metal, and is used for electrical fittings and machine parts.

Plastic-waste boards, which are marketed under proprietary names, are made with wood waste (chippings, shavings and sawdust), asbestos waste and flax waste mixed and bonded with phenolic and urea resins and pressed into boards with rough or smooth textures and, in some cases, with veneered faces.

Composite boards are made of two or more materials, such as fibreboard with a veneer of plastic, and plywood with a veneer of plastic. Plastic-faced wall boards are usually of this type. The method gives the advantages of rigidity and good insulation with the smooth decorative surface of the plastic and also keeps the cost down.

Transparent plastics are used chiefly in sheet form. They are made from thermoplastic materials and can be easily shaped when warmed. The material is lighter than glass. It is tough and does not readily break or splinter, but it is easily scratched. It can be surface hardened with a film of silica, but so far this method has been used only in the production of spectacle lenses. The transmission of ultra-violet rays is high. Where the special qualities of the material are desirable the sheets are used instead of normal glass in roof lights and windows. Corrugated transparent sheets are made for use on roofs covered with corrugated asbestos or metal. The transparent sheets are laid with the roofing sheets and no special fixing methods are required. But transparent plastic sheets cost more than glass and the weathering properties are not so good.

The weathering properties of plastics have not yet been tested over a long period. Generally, plastic products are very durable inside, but lose their high gloss when exposed to the weather.

Plastic materials for thermal insulation are made in two forms : built up with thin corrugated films of cellulose acetate to form sheets of cellular structure; and expanded or foamed plastic materials containing numerous small enclosed cells. Both forms are very light, durable and easily fixed.

Paints and varnishes with synthetic resins processed for use as drying

oils are now in wide use. The synthetic resins give a very smooth and superior finish. Cellulose paints made from nitro-cellulose, are also produced with synthetic resins.

Adhesives of synthetic resins are in wide use (see Adhesives).

Preservatives.—(See Wood Preservatives and Stone Preservatives.)

Pumice.—Igneous rock, of volcanic origin, very porous and of light weight. The finer kinds are used for rubbing down paintwork. Pumice is also used as an aggregate for lightweight concrete (see Concrete).

Rendering.—Covering on exterior walls consisting of a Portland cement and sand mix, or a lime-cement-sand mix. The latter is considered best as shrinkage is much less. (See Vol. III, Chapter 12.)

Weight : ½ inch thick, 6 lb. per square foot.

Roughcast.—A finish on a rendered undercoat for exterior walls consisting of spar or stone chippings. Small pebbles are sometimes used and this finish is often called pebbledash. The material is thrown on with a large trowel or small shovel, while the undercoat is still green.

Rubber.—Natural plantation rubber with various fillers and a small amount of sulphur is vulcanised at high temperatures, the process being varied according to the type of rubber required. Rubber can be moulded to any shape and is also produced in sheet form. In buildings it is widely used for flooring and in various forms for small fittings such as door buffers and draught prevention strip. Sponge rubber, containing small air cells, is used for cushions, seats, etc.

Rubber latex is used for a flooring which is laid *in situ* (see Fleximers).

Weight : Sheet rubber, 60 lb. per cubic foot.

Sand.—Consists of silica, a hard durable material, in fine grains. Sand is obtained from pits in many widely distributed areas throughout Britain, and also from river banks. Sea sand cannot be used in building unless the salt is removed, as the salt causes efflorescence. Pit sand is angular. River and sea sand is rounded. For mortars and concretes, pit sand is best, but the finer river sand is well suited to plastering (see Aggregate).

Weight : Dry, loose, approximately 70 lb. cubic foot.

Slag Wool.—(See Insulating Materials.)

Slate.—Formed in the earth from clay deposits by great pressure, heat and earth movements over millions of years. The chemical composition is chiefly silica, oxide of iron and alumina. Slate is a hard and very durable material. It is found in natural cleavage planes which enable it to be split into thin sheets.

Slate is quarried chiefly along the western side of Britain from Cornwall to Cumberland and Westmorland. But the chief source is the large deposits in North-west Wales.

Colour and thickness varies. The slates from Delabole, Cornwall and from Westmorland are thick, varied in colour and of rough texture, while

most of the Welsh slates are blue-grey, thin and of fairly even colour and rather smooth surface. (See Vol. II, Chapter 13.)

Weights :	Slate, slab, 14·75 lb. per inch of thickness.		
	Welsh slates, roofing :	First	5 lb. per square foot.
		Medium	6 ,, ,,
		Thick	8 ,, ,,
	Westmorland . . .		9-15 ,, ,,
	Cornish		6-9 ,, ,,

Steel and Iron.—Iron is found naturally in ores from which it is extracted by crushing, washing, weathering, calcination and smelting. This produces iron in pigs—short thick pieces. Pig iron consists chiefly of iron and carbon with small amounts of silicon, sulphur, phosphorus and other chemicals. There are various qualities, each suitable for some purposes.

Cast iron for structural use is usually grey cast iron.

Wrought iron has a much lower carbon content, which is reduced by puddling, blooming and rolling. The No. 3 Best Iron is the type used for most wrought-iron work. Formerly used for structural purposes, it has now been largely displaced by mild steel.

Mild steel is processed iron. It is called mild to distinguish it from hard steels. Mild steel is now widely used for rolled steel structural sections. It can be easily welded, has high strength in compression and tension and is easily machined.

Cast iron resists corrosion better than steels, but all iron and steel must be protected from corrosion.

Stone Preservatives.—There are only two safe methods of preserving stone : washing and scrubbing with cold or warm water, and steam cleaning. In both cases neither soda nor any other chemical should be added to the water.

Chemical stone preservatives depend for their action either on chemical reaction with the stone skin, by which the surface is said to be given much higher resistance to atmospheric impurities, or by applying a substance which seals the pores. One treatment consists of the application of a soluble silicate followed by a solution of chloride of calcium, which results in the formation of insoluble silicate of lime. The action of preservatives on stone is often harmful and at the best uncertain. The Building Research Station recommend washing and steam cleaning, using plain water; and for new stone coating the back of the stone with bitumen to prevent it coming in contact with brick or concrete backing so that harmful salts from these materials cannot be drawn into the stone, and the risk of staining is reduced.

Stones and Marble—These are natural products formed in the earth's crust by the action of great pressure, heat and earth upheavals.

Limestones and sandstones are termed aqueous rocks, because they were formed from clays and sands under water. *Limestones* consist of minute

shells from the water in which the stone was formed, and is composed chiefly of carbonate of lime.

Sandstones have been formed from older aqueous rocks, and is composed chiefly of silica.

Granite is an igneous rock, formed underground by the action of great pressure and heat. It consists chiefly of quartz, mica and felspar.

Marble and slate are termed metamorphic rocks. They are changed forms of igneous and aqueous rocks modified by subsequent pressure and heat.

(See Vol. I, Chapter 12.)

Weights :	Bath stone . . .	130 lb. per cubic foot.
	Portland stone . .	140 ,, ,,
	Sandstone . . .	140 ,, ,,
	Granite . . .	165 ,, ,,
	Marble . . .	170 ,, ,,
	Slate . . .	177 ,, ,,

Strawboard.—Consists of straw processed and compressed, and faced both sides with stout paper. It is manufactured in sheets or slabs 2 inches thick. The thermal and sound insulation value is high.

Weight, 3·6 lb. per square foot, 2 inches thick.

Thermal conductivity, $k = \cdot 6$.

Stucco.—A wall rendering of hydraulic lime and sand, oil painted to protect it from the weather. Stucco is now obsolete, having been displaced by Portland cement (see Rendering).

Thatch.—Roof covering of straw, reeds or heather. Straw is used in the Midlands and South-West and reeds in Norfolk and other parts where they are grown. Reed thatch is a very durable roofing, but straw thatch requires frequent repair and usually suffers damage by birds and mice. Untreated thatch very readily takes fire in a long drought, but suitable chemical treatment gives it high fire resistance. Heather is not satisfactory except for garden houses and other small temporary buildings.

(See Vol. II, Chapter 14.)

Timber.—There are two classes : *softwoods* obtained from coniferous trees with very narrow leaves, and *hardwoods* obtained from deciduous broad-leaved trees. But the two terms do not necessarily denote relative softness and hardness. Most of the timber used in buildings are softwoods, the most common being *redwood* (now the British Standard name for red deal, yellow deal, and Scots Pine). Oak is the most widely used of the hardwoods.

The outer part of the tree section is *sapwood* or albernum, and it is not suitable for constructional use as it readily decays. The inner part is the *heartwood* or duramen, and although this part readily decays in the living tree, it is the most durable in converted timber and hence only heartwood should be used in construction.

Some timbers contain oils which tend to preserve them—notably Western red cedar, which remains rot-proof for many years.

Large wood surfaces, formerly built up in panels, now usually consist of *plywood, blockboard or laminboard.* The thin sheets of which plywood are made are peeled off the round timber as it revolves against a blade. Plastic adhesives are now widely used to cement the thin sheets together, as these have high resistance to water (see Adhesives). Blockboard has a core of narrow strips of wood with thin outer sheets. Laminboard has a core of laminated wood between thin outer sheets. Very large thick rigid sheets are produced in both blockboard and laminboard. Hardwood veneers can be applied to all these materials.

(See Vol. III, Chapter 1.)

Weights:	Softwoods (redwood) .	30 lb. per cubic foot.
	Pitchpine . . .	41 ,, ,,
	Hardwoods (oak) .	50 ,, ,,

Waterproofers.—Compounds for waterproofing concrete, cement, brickwork and masonry. Some are used as a surface treatment on the wall or floor face, others can be incorporated in a cement mix to make concrete and rendering watertight throughout its thickness.

Waterproofers are of two main types: (1) those that fill the pores and so seal the material; and (2) those that cover the surface with a water repellant film but do not seal the pores. Waterproofing treatment of surfaces may also take the form of a paint application, of which bitumen emulsion is an example (see Paints).

There are numbers of proprietary waterproofers, most of which are colourless and transparent, though they slightly alter the appearance of the surface. The pore filling materials include silicate (waterglass), sulphates of aluminium and zinc and certain silicofluorides. The water-repellant types include linseed oil, various resins, gums and waxes, aluminous soap and materials derived from bitumen and tar.

Integral waterproofers are those which are incorporated with a cement mix. They include silicates, gypsum, chalk and talc, waxes, oils, and special soaps.

Waterproofers are made in powder, paste and liquid forms. Some are in emulsion form.

Wood Preservatives.—Timber may be attacked by certain fungi and insects. Preservatives are toxic liquids which prevent such attack, though it should be noted that some preservatives which will prevent the growth of fungi will not harm wood boring insects.

Coal-tar creosote is one of the best preservatives, but where exposed to the weather ordinary brush treatment is of little use as the creosote does not penetrate beyond the surface and soon weathers out. Immersion in cold creosote which is then gradually heated to 180-200° F. for an hour and then left to cool with the timber in it is much more effective. But pressure treatment in special plants by which the preservative is forced

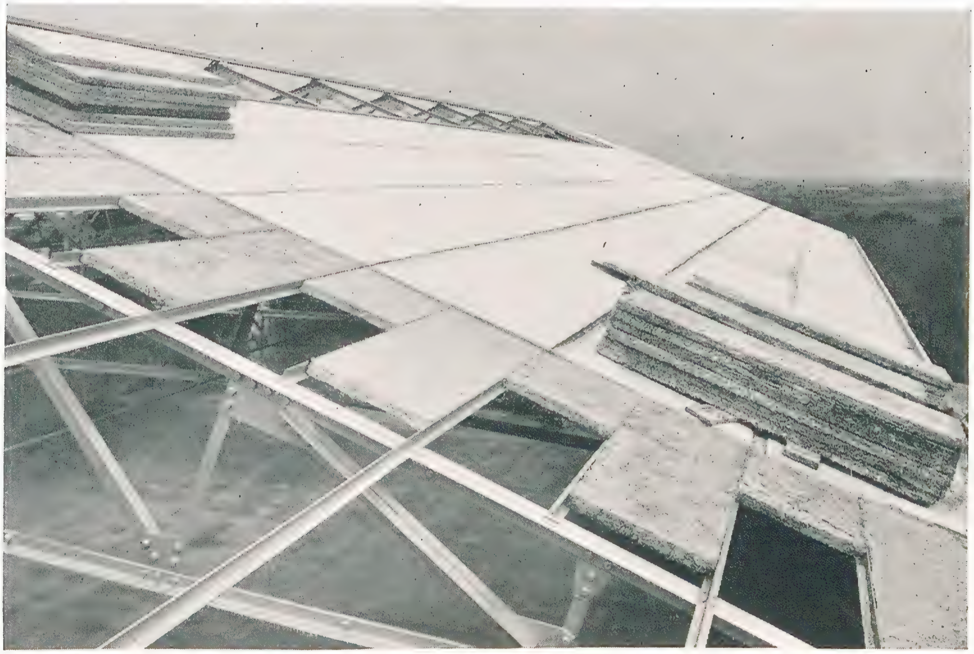


FIG. 219.—ROOF CONSTRUCTION WITH GYPKLITH LIGHT-WEIGHT BUILDING SLABS.

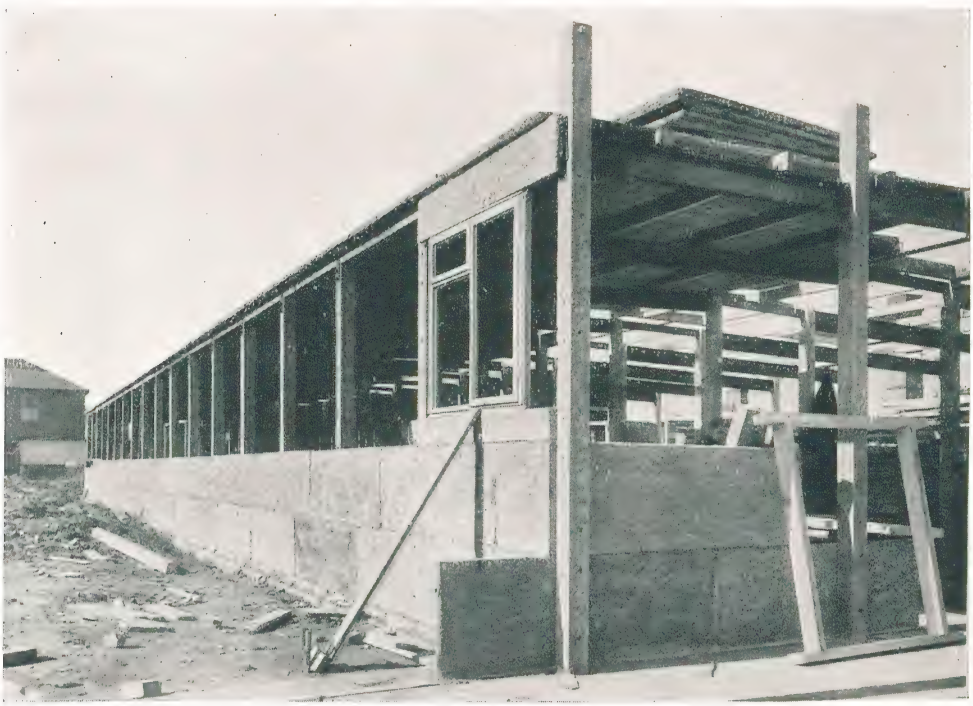


FIG. 220.—GYPKLITH LIGHT-WEIGHT BUILDING SLABS AS APPLIED TO EXTERNAL SLAB CONSTRUCTION.

(Both photos by courtesy of Gyproc Products, Ltd.)

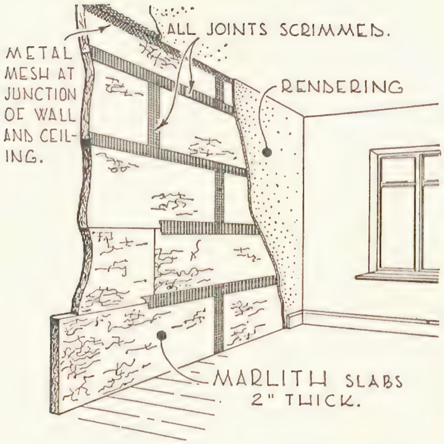


Fig. 221.—"Marlith"—a self-supporting partition.

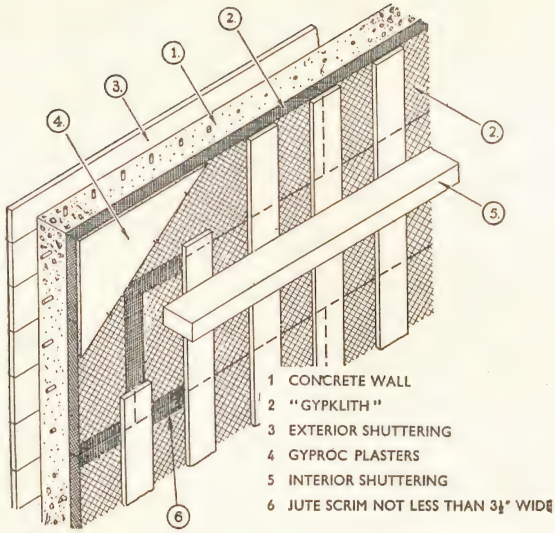


Fig. 222.—"Gypklith"—as permanent shuttering to concrete walls.

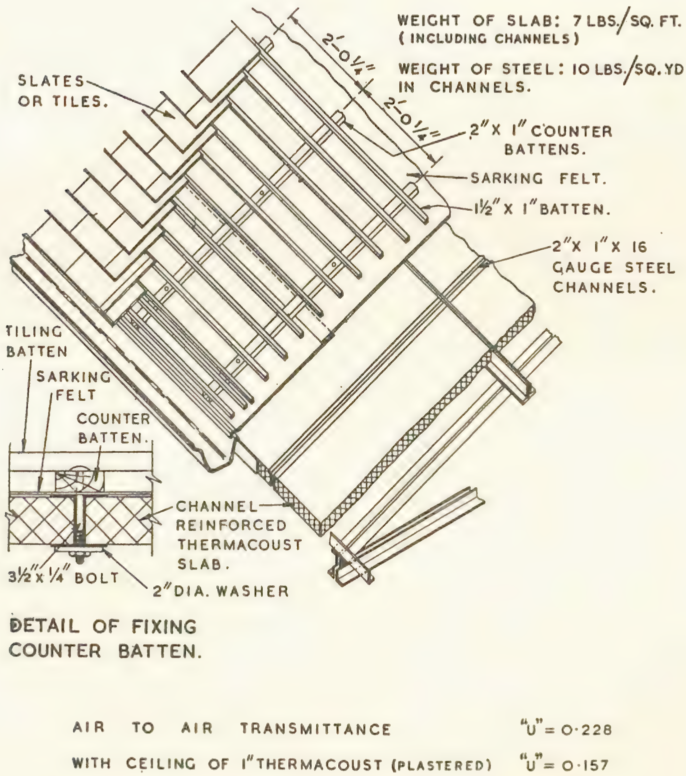


Fig. 223.—"Thermacoust" slabs (reinforced) as insulators to tiled roof.

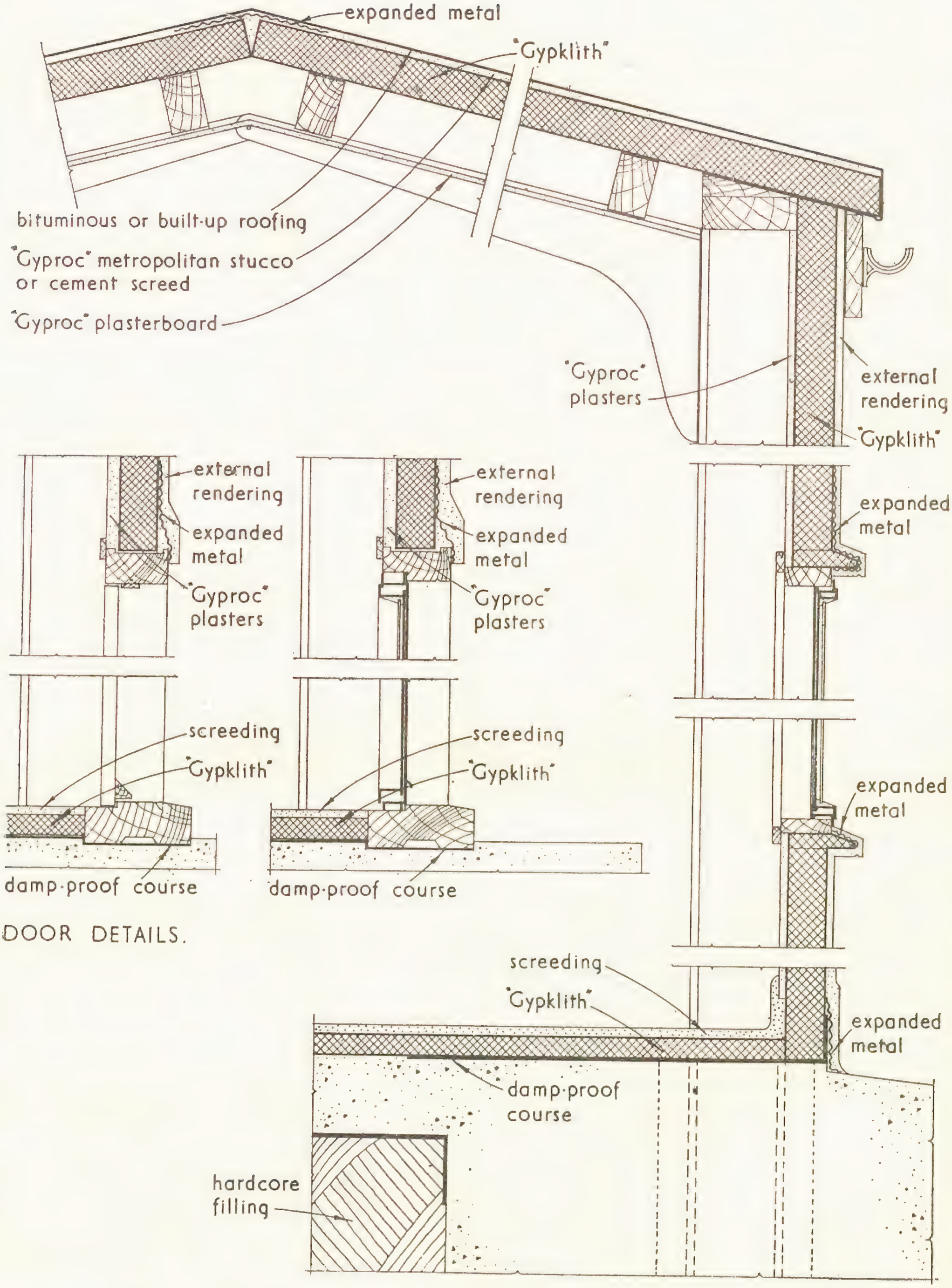


Fig. 224.—"Gypklith" slabs in pre-cast concrete framed building. 25 ft. span.

into the interior of the timber is best. Creosote has an objectionable smell and cannot be painted over. In consequence it is rarely used for inside work.

Metallic salts are used in some proprietary preservatives in the form of emulsions which cannot be washed out by rain. These salts are toxic and so prevent fungi and insect attack. The smell is slight and most brands can be painted over.

Non-proprietary chemicals which can be used in water solution for preserving interior timber are: *sodium fluoride* (2 to 4 per cent. solution) brushed on in two coats, and *magnesium silicofluoride* (an acid which attacks metals and glass) in a 5 per cent. solution applied in two coats. Both are colourless.

Oil paints and *bituminous paints* are good preservatives against both fungi and insects, provided the wood is properly seasoned and dry when the paint is applied.

(See Vol. III, Chapter 1.)

Wood-waste Plastic Sheets.—Building boards made from wood and other waste mixed with synthetic resins and pressed into sheets (see Plastics).

Wood Wool Slabs.—Made from wood fibre processed and cemented with an inorganic cementing agent, the slabs being pressed and matured. The *normal type* has the lowest density and strength, but the highest thermal insulation value. The *Special type* has greater density and strength. The *Reinforced* type is reinforced with light timber battens which give increased strength, and is intended chiefly for roof construction.

Weight: From $3\frac{3}{4}$ lb. per square foot for 1 inch thick normal slab, to $9\frac{1}{6}$ lb. per square foot for special 3-inch slab.

Standard sizes: 72 inches × 24 inches × 1, $1\frac{1}{2}$, 2 and 3 inches thick.

Zinc.—A whitish metal obtained from natural ores by processing. The best quality metal is ductile and can be bent without cracking. In normal atmospheres zinc forms a coating of oxide which protects it from corrosion. But acids and water containing lime attack it. In sheets zinc is used for roofing and fabricating rainwater goods. It is used for rustproofing ferrous metal in the forms of galvanising, sherardising and zinc spraying. Zinc oxide is used in paint manufacture as a pigment and retains its purity of tone better than lead.

Weight: 463 lb. per cubic foot.

Roofing sheets are usually 14, 15 or 16 zinc gauge.